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CREDITS

Appreciation is expressed to the Wisconsin fertilizer industry for the support provided through the Wisconsin Fertilizer Research Fund for research conducted by staff members in the Departments of Soil Science and Agronomy. Appreciation for financial support from the Wisconsin Aglime association through the tonnage fee for research on aglime is also gratefully expressed

The contribution of Kit Schmidt in the coordination of conference speakers is gratefully acknowledged. The assistance provided by Carol Duffy and Bonner Karger in preparation of this document is appreciated.

2007 Wisconsin Crop Production Association Distinguished Service Awards

WCPA Distinguished Organization Award
Kettle Lakes Cooperative
Random Lake
{For Exemplary Industry Professionalism}

WPCA Educator's Award
Larry Bundy
University of Wisconsin-Madison
{For Leadership & Commitment to Educational Excellence}

WCPA Outstanding Service to Industry Award
Todd Cardwell
Agriliance
{For Exemplary Service to the Industry}

WCPA President's Award
Tom Gearing
Agriliance
{For Dedication, Service, and Leadership}

2006 – 2007
Scholarship Recipients

Wisconsin Crop Production Association Scholarships

Amy Freidig, UW-Madison
Kevin Schneider, UW-Madison
Daniel Crockett, UW-Stevens Point
Rachel Paskey, UW-River Falls
Steven Wilkens, UW-Platteville
David Haag, Southwest Wisconsin Tech
Holly Sykora, Fox Valley Tech
Brian Schreiber, Fox Valley Tech
Kyle Welscher, Western Wisconsin Tech

R.D. Powell Memorial Scholarship

Emily Sneller, UW-Madison
Ana Wells, UW-Madison

Leo Walsh Graduate Fellowship

Matt Repking, UW-Madison

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Papers in the order of presentation at the conference. A paper is not included in the proceedings for all presentations (a page is included, however, for note taking).

Session 2B — Nutrient Management: Farm & Field

Session 2C — Pest Management & Stewardship

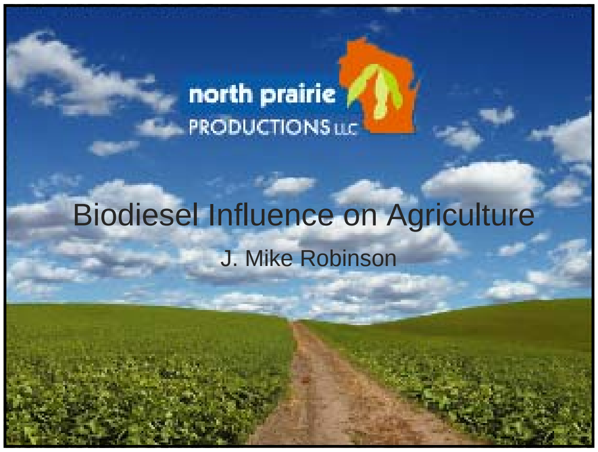
Session 5B — Pest Management
Hot Topics

BIOFUELS: GROWING ALTERNATIVES FOR WISCONSIN

Maria Redmond [1/]

This presentation thoroughly discusses the role of biofuels, specifically ethanol and biodiesel, in the transportation sector. Presenter will provide attendees with valuable information of why there is great interest in biofuels, a breakdown of the benefits and challenges of biofuel use, how biofuels effect the environment and local economy, and what the State of Wisconsin is doing to promote biofuels in the state.

[1/] Alternative Fuels Policy Analyst, Wis. Department of Agriculture, Trade and Consumer Protection.



Project Development

Project Started	Funding for Business Plan	Seed Funding	Equity Drive	Ground Breaking	Commissioning
Spring 2005	September 2005	June 2006	September 2006	March 2007	November 2007

Why North Prairie?

- Management Team (business owners, financial expertise, agriculture operators, process technologist and end users)
- Key Partners (Landmark, Desmet Ballestra, Boldt, Foth & VanDyke, Jacobson, First Cap Ag, Eco-Energy, Michael Best & Friedrich)
- Location - Potential crush facility
- Low Conversion Cost (scale, energy, labor, catalyst usages, etc.)
- Early to Market, Wisconsin Leader
- Community Based Venture

Distribution of Production Facilities

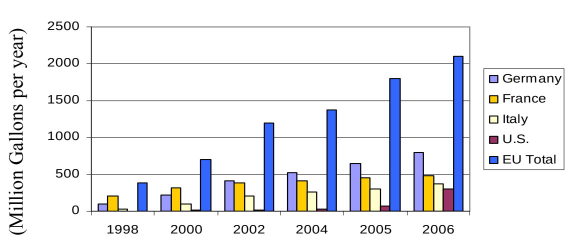
Ethanol

Source: www.ethanolrfa.org/

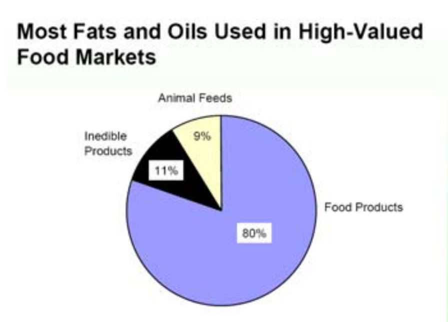
Biodiesel

Source: National Biodiesel Board, www.biodiesel.org

Global Biodiesel Consumption



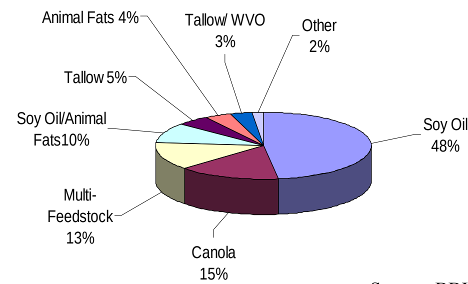
Current Uses of Oil in US



Biodiesel Feedstock Sources

Type	***Example***
➢Virgin Vegetable Oil	*Soy, Canola, Sunflower, Cottonseed, Corn*
➢Animal Fats	*Poultry, Lard, White Grease, etc.*
➢Waste Vegetable Oil	*Used Fryer Grease*
➢Imported Feedstocks	*Palm, Coconut*
➢New Non-edible "Biodiesel" feedstocks	*Algae, Jatropha, Camelina, Other?*

Feedstocks for Future Biodiesel Production



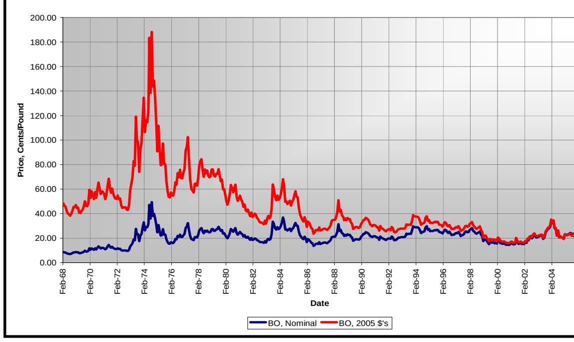
Source: BBI

The Future of Soy for Biodiesel

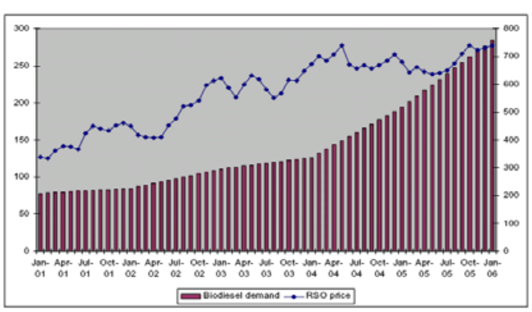
- Soy was not developed as a biodiesel crop, but will dominate as main biodiesel feedstock in the near-term.
- Will not crush for oil.
- Higher oil yield content – 1% increase across U.S. yields an additional 240 gallons
- Genetically manipulate acid content to improve cold flow qualities of Biodiesel

Real Soybean Oil Prices

CBOT Nearest Futures Adjusted by CPI



Europe: Biodiesel Impact on Rapeseed



European Rape Seed Oil Prices vs. Biodiesel Demand.

Source: Louis Dreyfus Commodities, Biodiesel Presentation, Februarys 6, 2006 presented at National Biodiesel Board annual Conference, San Diego, CA.

Oil Yields form Various Crops

Crop	Oil Content	US gallons ac^{-1}	Years to production#
Soybean	18-20%	48	0.35
Flax	35-40%	51	0.30
Camelina	29-39%	61	0.30
Rape	37-50%	127	0.33
Sunflower	25-45%	102	0.4
Peanut	40-55%	113†	0.4
Jatropha	40-48%	460	>4
Palm	40-50%	635	>3
Castor bean	40-50%	278	<1
Algae*	10-85%	40,000‡	<1

*Algae would be grown in large raceway ponds along coastal areas
Data taken from Journey to Forever, 2006, except:
†Taken from Duke, 1983.
‡Taken from Hamilton, 2006.

Camelina

- •Montana State University – 3rd Year of Research. Previous work at University of Minnesota
- •Originated in Northern Europe
- •Similar to Mustard, 29-39 percent oil
- •Production costs of 2-3 cents per pound ($35-$45/acre and yields of 1,400 lbs acre)
- •Duane Johnson, a Montana farmer, “It takes $4.33 per bushel to break even in canola production. Camelina production needs $1.23 for a break-even price."

Algae

- High Oil yield
- Uses Water of Marginal Quality (salt water)
- Combine with Coal fired Power Plants or waste water streams.
- Requires Technology Development
- South Africa Moving forward with Large scale production. (Billion + Gallons)

Future Biodiesel Crop?

- Different Soy Bean?
- High Oil yield
- Low cost of production
- Grows on marginal soils
- Low water consumption
- Less concerned with Genetic Modifications
- Find a use for by-product

BIOFUEL IMPACTS ON MIDWESTERN AGRICULTURE

Chad Hart[1]

Abstract

Ethanol production from corn doubled from 2001 to 2005 and will likely double again before the end of 2008. Biodiesel production tripled from 2004 to 2005 with continued growth expected in 2007. Biofuels have become the driving force in the U.S. crops sector. But in this race between biofuels, ethanol has emerged as the main biofuel impacting U.S. agriculture today. The growth in the biofuels industry has created a strong demand pull, especially for corn. Over the past 5 months, we have seen corn prices increase dramatically. In mid-September 2006, the December 2007 corn futures contract was priced at $2.50/bushel. On December 19, 2006, that contract stood at $3.73/bushel. Prices rose throughout the harvest period despite the third largest corn crop on record coming in 2006. This strength in corn prices has been accompanied by increases in soybean and wheat prices. And this strength is not limited to next year as futures prices and industry forecasts project corn prices above $3.00/bushel, soybean prices above $6.00/bushel, and wheat prices above $4.00/bushel for the next several years.

Thus, the price signals to Midwestern crop producers are strongly indicating a need for more crop acreage in the coming years, especially for corn. Preliminary estimates from the Food and Agricultural Policy Research Institute show U.S. corn acreage increasing to nearly 86 million acres in 2007 with continuing increases beyond that. By 2014, corn acreage is projected to reach 91.5 million acres. Over half of the increase in corn acreage comes from the Corn Belt and Great Lake states. Wheat acreage is projected to rise by 2 million acres in 2007. The increases in corn and wheat acreage are mainly at the expense of soybean acres, as soybean acreage is projected to decline by 4.5 million acres in 2007. Also, over the next 2 years, an additional 5.5 million acres are expected to enter row-crop production.

Ethanol will become the second largest demand for corn, trailing only livestock feeding and overtaking exports in 2007. Corn usage for livestock feeding and exports are projected to decline slightly in 2007, given the higher corn prices. The long-term impacts on the livestock industry depend on several factors, including the relative strength of livestock prices, the ability of U.S. livestock to utilize the co-products from ethanol production, and the ability of U.S. crop producers to match their production growth with the demand growth we are currently seeing.

[1] Head of Biorenewables Policy Division, Center for Agricultural and Rural Development, and U.S. Policy and Insurance Analyst, Food and Agricultural Policy Research Institute, Iowa State University, Ames, IA 50011-1070

MAINTAINING SOIL QUALITY GAINED WITH CRP

Judy Derricks [1/]

{This page provided for note taking}

[1/] USDA, Natural Resource Conservation Service.

WILL INCREASING CORN ACREAGES IN WISCONSIN NECESSARILY LEAD TO HIGHER RUNOFF SEDIMENT AND PHOSPHORUS LOSSES?

Laura Ward Good [1/]

Currently there are more than 600,000 acres in Wisconsin enrolled in the USDA's Conservation Reserve Program (CRP). The contracts for approximately 44% of these acres may expire in 2007 and 2008 (Farm Service Agency, 2006). The fate of these lands is uncertain, though a likely scenario, given current rising demand for corn, is that at least a portion will go into a corn-based row crop rotation. These CRP lands were removed from production because of their vulnerability to erosion. Soil and nutrient losses from CRP lands kept in perennial cover are extremely low. If these highly erodible lands go into corn production, will the increasing runoff sediment and nutrient loads lead to disastrous water quality declines? Are there ways to manage corn on former CRP lands that will keep the soil quality and conservation gains from the Conservation Reserve Program from being totally lost?

To answer these questions, I used the cropland soil erosion and runoff phosphorus loss estimation capability of the Snap-Plus nutrient management planning software to evaluate the consequences of different corn rotations and tillages on highly erodible fields (Snap-Plus, 2006). Snap-Plus includes RUSLE2, the Natural Resource Conservation Service's (NRCS) current field-level soil loss estimation tool for conservation planning, and the Wisconsin P Index calculator. The Wisconsin P Index estimates phosphorus (P) delivery from a field to the nearest surface water (Bundy and Good, 2006). If the distance from the field to the stream in the program is set at zero, the P Index value can be used as an indicator of field-edge runoff losses. The RUSLE2 soil loss calculations have been extensively validated (Foster, 2005), and both the RUSLE2 and the P Index appear to be doing a reasonable job of assessing the effects of varying management practices and field conditions on runoff sediment and P losses from Wisconsin fields (CALS, 2005). An additional Snap-Plus/RUSLE2 output that I used for assessing the cones-quences of establishing corn rotations on soil quality is the Soil Conditioning Index, a measure of soil organic matter status over a rotation.

The information requirements to assess soil loss with Snap-Plus are: field's location (county), soil type, slope, slope length, crop rotation, yields, and tillage practices. Additional requirements to calculate P runoff potential with the P Index are soil test P and manure and P fertilizer rates, timing, and method of application. For representative highly erodible field sites, I selected eleven soil mapping units with steep (soil mapping unit "D") slopes from counties with significant CRP acreages (Table 1). Conservation Reserve Program acres are predominately in the southwest, south central, and northwest parts of the state and in a few of the eastern counties. The fields I chose are not statistically representative of CRP sites in Wisconsin as the data that would allow this is not available, but they are examples of sites that might be in CRP. For slopes and slope lengths, I used the default ("typical") values assigned by NRCS for each mapping unit. I assigned a moderate soil test P value of 20 ppm to each field.

For each field, I ran Snap-Plus with ten different crop rotation and tillage combinations: established grass hay (cut three times during the growing season), no-till continuous corn for grain (Cg: NT); strip-till continuous corn for grain (Cg: ST), no-till continuous corn grain with half of the stalks baled (Cg-baled: NT), no-till rotation with 2 years of corn for grain followed by

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[1/] Assistant Scientist, Dept. of Soil Science., Univ. of Wisconsin-Madison, 1525 Observatory Dr., Madison, WI, 53706.

soybeans (Cg-Cg-S: NT), continuous corn for grain with a one-pass tillage - a field cultivation (Cg: Fcult), chisel-plowed continuous corn for grain (Cg-CP), no-till continuous corn silage (Cs: NT), continuous corn silage with one-pass tillage (Cs: Fcult), and chisel-plowed continuous corn silage (Cs-CP). All operations were conducted on the contour. The difference between the no-till and strip till managements is that the strip-planter disturbed a wider zone of the surface than the no-till planter. RUSLE2 soil loss estimates are quite sensitive to yield levels in corn for grain and decrease with increasing yields; therefore, it is important to select representative yields to get truly representative soil loss estimates. For corn yields, I used the 75th percentile yield for each soil's potential corn yield range as identified in the University of Wisconsin-Extension soil fertilizer recommendations (Laboski et al., 2006). No manure or fertilizer applications were included in this Snap-Plus analysis.

Table 1. Location and site characteristics of fields used for soil and phosphorus loss estimations

Location (County)	Field slope	Field slope length	Soil map symbol	Soil name	Surface texture	Tol. soil loss (T)
	%	ft				T/acre/yr
St. Croix	16	100	AmD2	Amery	loam	5
Pierce	16	30	167D2	Derinda	silt loam	3
Iowa	14	150	DhD2	Dodgeville	silt loam	4
Grant	12	150	DuD2	Dubuque	silty clay loam	3
Dane	16	100	DuD2	Dunbarton	silt loam	2
Eau Claire	16	85	EmD2	Elkmound	loam	2
Trempealeau	16	150	GaD2	Gale	silt loam	3
Dunn	16	100	275D2	Hayriver	Fine sandy loam	3
Fond du Lac	16	100	HmD2	Hochheim	loam	5
Rock	16	100	KdD	Kidder	sandy loam	5
Richland	16	100	254D2	Norden	silt loam	3

Erosion

Estimated erosion increased with increasing crop residue removal and soil disturbance across all sites (Fig.1 and Table 2). Estimated soil loss for grass hay was minimal for all sites (0.1 ton per acre). Soil loss was greater for all the corn rotations. All no-till corn for grain soil loss, however, was below 1 T/acre/year, and soil loss for strip-tilled corn for grain was below the NRCS standard for tolerable soil loss (T) at all sites. The fields with soils with the lowest T values (2 T/acre/year, Dunbarton and Elkmound soils) could not meet T if the corn stalks were baled or if soybeans were added to the rotation every third year. Six of the fields with corn for grain could not meet T with one-pass tillage and only two could meet T with a chisel plow system (Hochheim and Kidder soils). Fields with corn silage had very high RUSLE2 soil losses that were 4 to more than 10 times T and 80 to 400 times more than that for the grass hay, even with no-till.

Less steep fields than these would be expected to lose less soil under the same rotations. On one of the most vulnerable soils in the example group (Dunbarton), the no-till corn-soybean rotation that did not meet T for the example field would meet it with a lower slope (DuC2, 9% slope). On one of the least erodable soils in the example group (Hochheim), no-till corn silage could meet T on a 9% slope (HmC2). One interesting observation that came from some additional Snap-Plus runs with these fields is that, although conducting all operations on the contour was very important for keeping soil loss estimates low for all systems with tillage, including strip tillage, no-till planting up-and-down the slope rather than on the contour generally only increased soil loss by 0.1 T/a/yr.

Figure 1. Mean estimated rotational erosion for all example fields by rotation and tillage.

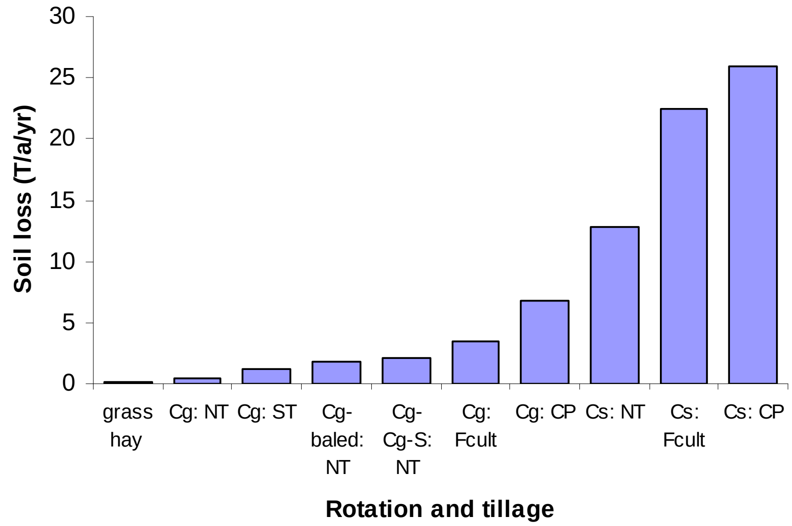


Table 2. Mean, maximum and minimum estimated soil loss for all example fields by rotation and tillage in T/a/yr. †

	Grass hay	Cg: NT	Cg: ST	Cg-baled: NT	Cg-Cg-S: NT	Cg: Fcult	Cg: CP	Cs: NT	Cs: Fcult	Cs: CP
Mean	0.1	0.5	1.2	1.8	2.2	3.5	6.8	13	23	26
Max	0.1	0.8	2.3	3.2	3.5	5.7	10.7	20	37	44
Min	0.1	0.2	0.4	0.7	1.0	1.7	3.1	8	13	15

† Abbreviations: Cg = Corn for grain, S= Soybeans, Cs = Corn silage, NT= No-till, ST=Strip-till, CP= Chisel plow, Fcult = Field cultivation

Runoff Phosphorus Losses

For these example fields, the primary form of P in runoff is expected to be particulate, or sediment-bound P. Consequently, the trend toward increasing P in runoff with increasing crop residue removal and soil disturbance mirrors that for soil loss (Fig. 2). All of the fields were assigned the same soil test P (20 ppm) for this analysis; P losses would be proportionately lower if the soil test P was lower and proportionately higher at higher soil test P values. In this analysis, none of the fields received manure or broadcast applications of P fertilizers. Such applications would have lead to increased risks of P in runoff in forms not directly bound to sediment.

Soil Conditioning Index

The Soil Conditioning Index (SCI) is a comparatively new index calculated by RUSLE2 and used by the NRCS to indicate the effect of a management system on soil organic matter (USDA-NRCS, 2005). It takes into account crop biomass additions and removals, field operations, and erosion. If the calculated SCI value is positive, organic matter will be increasing with the rotation and the reverse is true if it is negative. An illustration of SCI values with differing rotations for one example field is shown in Fig. 3. Almost all of the rotations with corn for grain (the exception is except for Cg: CP) had positive SCI values, while all of the corn silage rotations had negative SCI values. All of the example fields exhibited the trends shown in Fig. 3.

Figure 2. Mean rotational average P Index values for all example fields by rotation and tillage.

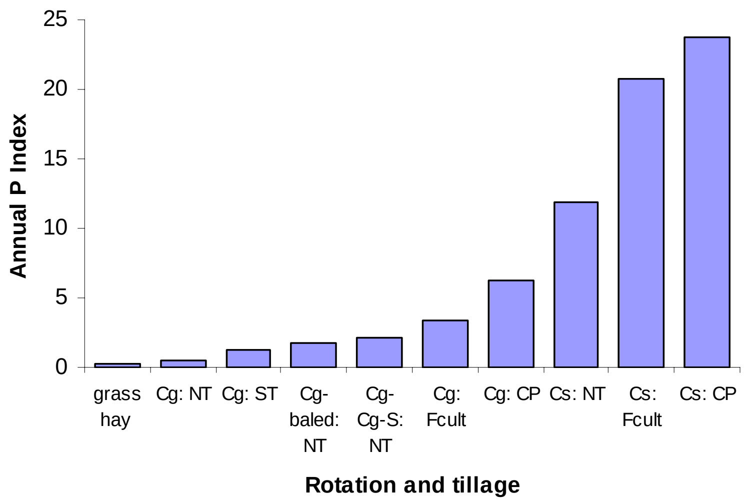
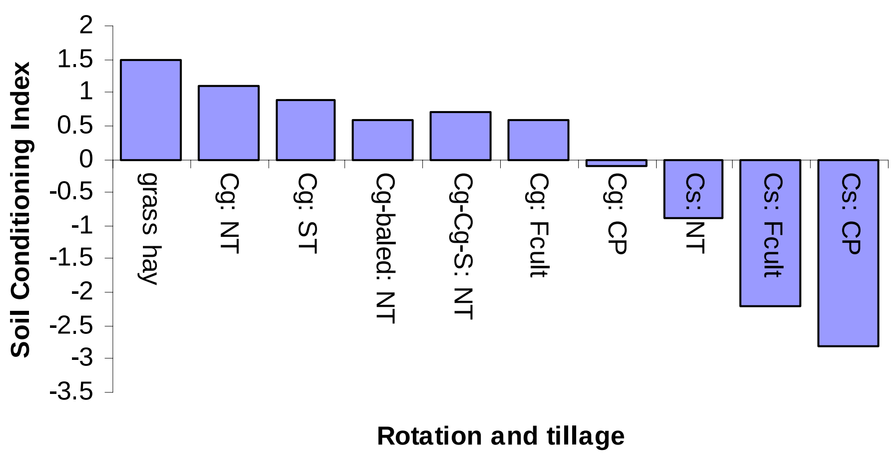


Figure 3. Soil conditioning index for a Grant County Dubuque silty clay loam field, 12% slope with different rotations and tillages.



Can the Beneficial Effects of Crop Residues Be Replaced with Manure Applications?

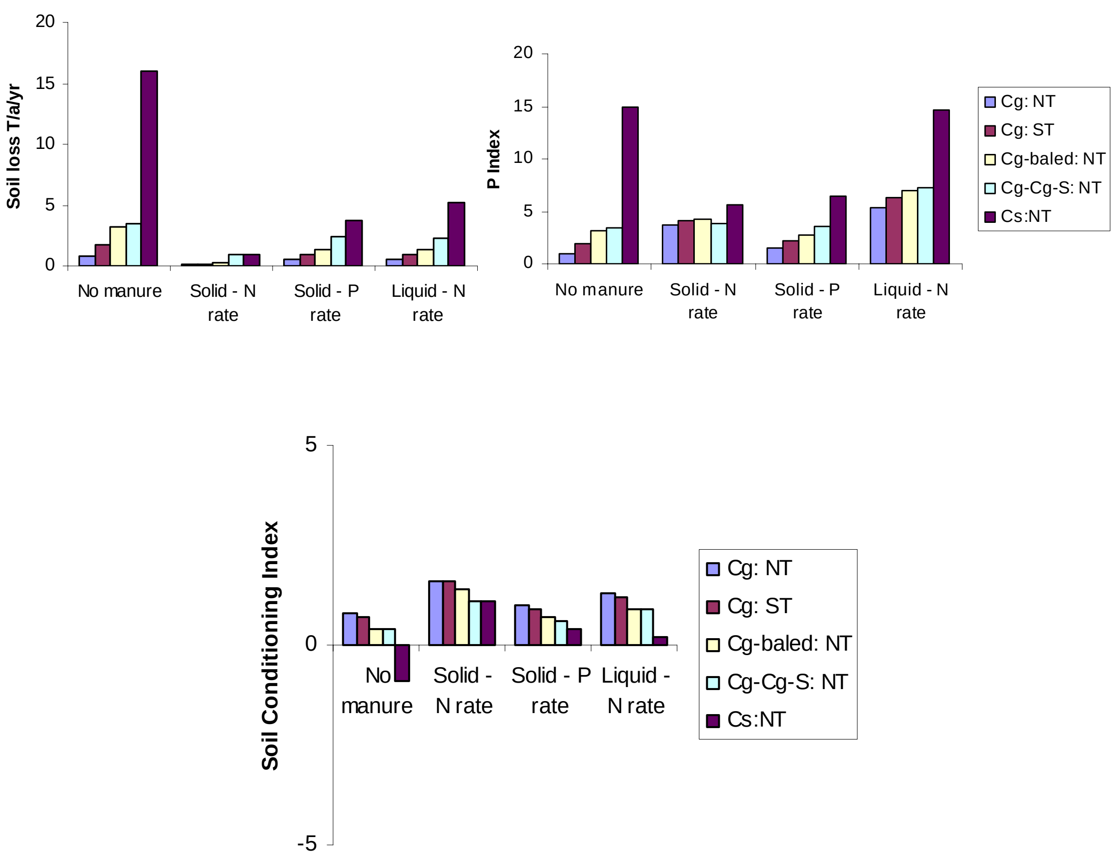
Expected increases in soil and nutrient losses and decreases in soil organic matter with corn rotations are directly related to the quantity of crop residues left on the soil surface. In situations where corn silage is more valuable to growers than corn for grain, is there a way to remediate the removal of the corn plant by replacing it with some other organic matter on the soil surface? Currently, the most common organic matter amendments in Wisconsin are animal manures.

Adding manures to the soil surface can reduce soil loss but also increases the amount of P and other nutrients on the surface that can be washed away in runoff.

To answer the question of how much manure applications can be used to reduce sediment losses without increasing the risk of runoff P losses to unacceptable levels, I ran Snap-Plus for two of the example fields using several rates and kinds of manure applications in the rotations. Since most of the example fields are too steep for winter applications, I set the manure applications in the fall after harvest. The manure applications were: solid dairy manure with bedding (24% dry matter) applied at a rate to meet the nitrogen (N) need for corn (40 T/a), solid dairy manure applied to meet the P recommendations for corn (8 T/a), and liquid dairy manure (6% dry matter) to meet the corn N rate.

Soil loss was dramatically reduced with the heavier dairy manure application as shown for the Dunbarton silt loam in Fig. 4. It was below T for this soil (2 T/a/yr) for all no-till rotations, even continuous corn silage. The manure applications also increased SCI values in proportion to the manure dry matter applied. No-till corn silage had a positive SCI, indicating positive organic matter accumulation, with any of the three rates of manure. Conversely, the manure applications, particularly when applied to meet corn N needs, dramatically increased runoff P loss potential.

Figure 4. Estimated soil loss, P index, and soil conditioning index values for a Dane County Dunbarton silt loam, 16% slope, with varying rates and types of unincorporated dairy manure applications, rotations and tillages.



Conclusion

Converting CRP from permanent grass lands to corn will certainly increase sediment and phosphorus loads in runoff from these areas. However, with careful management that minimizes tillage and retains a significant amount of crop residue on the surface, these losses will be minimized. Harvesting the entire corn plant as is done for corn silage will lead to soil losses that are orders of magnitude higher than tolerable soil loss. This can be mitigated with replacement of the plant material with some other organic material such as manure. Unincorporated manure applications, however, will increase the risk of phosphorus losses in runoff.

The Snap-Plus software is designed to be used by growers, agronomists and other agricultural professionals in Wisconsin. The field level information it requires is readily available to growers. It can help growers assess potential sediment and phosphorus losses resulting from converting grass lands to row crops and can help them pick management practices to minimize these losses.

References

Bundy, L.G., and LW. Good. 2006. The Wisconsin Phosphorus Index. Website: http://wpindex.soils.wisc.edu/index.php

CALS. 2005. The Wisconsin Buffer Intiative. A Report to the Wisconsin Department of Natural Resources by the University of Wisconsin-Madison, College of Agricultural and Life Sciences.available at http://www.drs.wisc.edu/wbi/

Farm Service Agency. 2006. Summary of Active and Expiring CRP Cropland Acres by County. Available at http://content.fsa.usda.gov/crpstorpt/11Approved/rmepeii_r1/WI.HTM

Foster, G.R. 2005. Science Documentation, Revised Universal Soil Loss Equation, Version 2. Agricultural Research Service, Washingotn D.C. Available at: ftp://fargo.nserl.purdue.edu/pub/RUSLE2/RUSLE2_Program_File/

Laboski, C.A.M., J.B. Peters, L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable and fruit crops in Wisconsin. UWEX Pub. A2809. Univ. of Wisconsin-Extension, Madison, WI.

Snap-Plus,2006. Snap-Plus Nutrient Management Software. Available at www.snapplus.net.

USDA-NRCS, 2005. Soil Conditioning Index, factsheet. Available at http://www.wi.nrcs.usda.gov/technical/consplan/rusle.html

PHOSPHORUS LOSSES FROM CORN FIELDS [1/]

John C. Panuska [2/]

Abstract

A principal focus of water quality management efforts in the U.S. is related to nutrient, specifically nitrogen (N) and phosphorus (P), export in runoff from agricultural lands. The focus of this discussion is to investigate the influence of residue levels and manure addition on particulate P delivery by runoff. Rainfall runoff samples were collected from three hydrologically isolated hillslope tracts in conservation tillage with the following treatments: corn-grain (CG); corn-silage (CS); and corn-silage with fall manure addition (SM). Rainfall-runoff, frost free (FF) events were sampled from May 2004 through September 2005. Samples were analyzed for solids mass, P in the dissolved and particulate forms, sediment P-mass distribution in five different particle-size classes along with particle and aggregate size distributions, and aggregate stability. This discussion is limited to soil and total phosphorus (TP) loss and the distribution of TP mass over five particle size classes in the sediment.

The runoff volume and soil loss from the CG treatment was significantly lower than the lower residue CS treatments. The majority of the annual P loss occurred in the particulate P form for all the monitored events. The majority (~ 57%) of the sediment P mass was contained in particles less than or equal to 50 µm in size (clay and silt). The increased transport of fine P enriched particles increases the potential for downstream water quality degradation. This research highlighted how differences in land management practices influence nutrient and sediment export from corn fields. The increased interest in bio-fuel production could result in high rates of bio-mass removal. The corresponding decrease in surface residue could, if not properly managed, increase soil loss in-turn degrading soil health and downstream water quality.

Introduction

Water quality management efforts in the U.S. over the past 30 years have been driven primarily by the passage of the Clean Water Act in 1972. Initially, pollution control efforts focused on point source controls resulting in great progress toward reducing contributions from these sources. However, surface and groundwater quality problems still persist for which non-point sources have been implicated. Nutrient export from agricultural lands, specifically N and P, has been identified by the U.S. Environmental Protection Agency (USEPA) as the major cause of excessive aquatic plant growth in lakes and rivers of the U.S. (Parry, 1989; USEPA, 1995; USEPA, 1996) reducing beneficial use of the receiving water. Accelerated aquatic plant growth or *cultural eutrophication* impacts aesthetics, fisheries, recreation, industrial and drinking water use resulting in local, regional and national economic impacts.

[1/] U.S. EPA - STAR grant project titled: *Measuring and Modeling the Source, Transport and Bioavailability of Phosphorus in Agricultural Watersheds.*

[2/] Natural Resources Extension Specialist, Biological Systems Engineering Dept., Univ. of Wisconsin-Madison, 460 Henry Mall, Madison, WI, 53706.

Phosphorus is transported in both dissolved (dissolved P, DP) and particulate-bound (PP) forms, with the latter dominating overall P losses in row-cropped agricultural systems (Logan, 1980, 1982; Ginting et al., 1998; Gillinghan and Thorrold, 2000; Uusitalo et al., 2001). Because clay and other fine-grained materials (i.e., organic matter (OM), silt) have a high specific surface area, P and other chemical contaminants are strongly sorbed to, and readily transported with these particles. The reduction in soil loss therefore has a secondary benefit of P loss reduction.

The overall goal of this study was to investigate the influence of agricultural management practices (e.g., residue cover, tillage, manure management) on the delivery of P in particulate and dissolved forms in both rainfall and snowmelt runoff. This discussion uses sediment particle size data collected during the 2004-05 frost-melt (November-March) (FM) and the 2004 frost free (April-October) (FF) periods. Data collected during the 2004 FF period were used to evaluate the sediment and total P losses, while both FM and FF data were used to determine the sediment P mass-particle size relationship. This study will focus on three areas: (1) the relationship between crop residue and soil loss, (2) the relationship between soil loss and P loss, and (3) the distribution of P by particle size.

Methods and Materials

Field monitoring was conducted on a terraced hill-slope at the Univ. of Wisconsin Arlington Agricultural Research Station. The southern halves of three terraced fields, designated as corn-grain (CG); corn-silage (CS); and corn-silage with fall manure addition (SM), respectively, were instrumented and monitored for this research project. Soils were silt loam - Ripon series (fine-silty, mixed, mesic Typic Argiudolls). Each field was an independent first order watershed due to the existence of terrace channels at the up- and down-slope boundaries. Within each field, storm-event surface runoff samples were collected from hydrologically isolated hill-slope tracts 15 ft wide and 120 ft long resulting in a tract area of 1,800 ft^2 (0.04 ac). The average slopes for the (CG), (CS) and (SM) tracts were 7.0, 8.2, and 8.4%, respectively.

Edge-of-field runoff sample collectors were installed at the downstream end for each hillslope tract. Rainfall data were collected from continuous and bulk gauges located on-site and from the Arlington Agricultural Research Station headquarters located approximately 3.7 miles due south of the site. The NOAA-certified gauge at the Arlington Agricultural Research Station was used to provide the 30-yr (1971-2000) normal precipitation data, to fill gaps in the absence of on-site data or when precipitation occurred primarily as snowfall. The edge-of-field monitoring sites used a flow-dividing bulk collection system. Runoff and sediment were collected on plastic-covered triangular collectors designed, to direct flow into a 4-inch diameter PVC collector pipe. The collector pipe then discharged into a series of three buckets, the first two (B1 and B2), which were 5-gallon Samson® HDPE buckets equipped with flow-dividing crowns as specified by Pinson et al. (2004). The third bucket (B3) was a 10-gallon tank that did not include a flow divider. Each divider head was laser-cut from stainless steel and designed with twenty-four V-notch weirs (2.5 inches in height) circumscribing its perimeter, and capable of passing a total flow of 106 gpm. The flow-divider crowns are designed to collect only a fraction of the total runoff volume.

<u>Land Management</u>

All tracts were planted with corn (*Zea mays* L.) under conservation tillage, fall chisel plow followed by spring field cultivation prior to planting. The primary tillage depth was 8 inches using a Glencoe chisel plow with twisted shovel followed by secondary tillage using a field cultivator to a depth of 3 inches. The planting density was 32,000 seeds/ac and a row spacing of 32 in was used throughout the study. The tillage orientation was up-and-down the slope for all treatments. The management operations included in the study are summarized in Table 1.

Table 1. Field management operations, dates, residue cover and crop yields by site.

Site ID	Year	Crop Type	Plant Date	Harv. Date	Tillage Date	Tillage Implement	Crop Row Orientation	Residue Cover [1]	Initial Bray-1 P [2]	Fert. Appl. [3]	Manure App. [4]	Crop Yield [5]
AR1	2003	Corn Grain	17-May	16-Oct	10/23/2002 5/16/2003	Fall chisel plow Field cultivator	On contour	51%	58	Starter only	None	95
AR1	2004	Corn Grain	7-May	26-Oct	11/7/2003 5/7/2004	Fall chisel plow Field cultivator	Up / Down Slope	57%	ND	Starter only	None	130
AR1	2005	Corn Grain	26-Apr	10-Oct	10/12/2005 5/7/2004	Fall chisel plow Field cultivator	Up / Down Slope	41%	38	Starter only	None	130
AR2	2003	Corn Silage	17-May	6-Nov	10/23/2002 5/16/2003	Fall chisel plow Field cultivator	On contour	10%	66	Starter only	None	1.9
AR2	2004	Corn Silage	7-May	27-Sep	11/7/2003 5/7/2004	Fall chisel plow Field cultivator	Up / Down Slope	25%	ND	Starter only	None	1.7
AR2	2005	Corn Silage	26-Apr	8-Sep	10/12/2005 5/7/2004	Fall chisel plow Field cultivator	Up / Down Slope	21%	51	Starter only	None	1.9
AR3	2003	Corn Silage	17-May	6-Nov	10/23/2002 5/16/2003	Fall chisel plow Field cultivator	On contour	15%	17	Starter only	Fall + plowed 29 lb P/ac	2.0
AR3	2004	Corn Silage	7-May	27-Sep	11/7/2003 5/7/2004	Fall chisel plow Field cultivator	Up / Down Slope	18%	ND	Starter only	Fall + plowed 48 lb P/ac	1.7
AR3	2005	Corn Silage	26-Apr	8-Sep	10/4/2005 5/7/2004	Fall chisel plow Field cultivator	Up / Down Slope	15%	74	Starter only	Fall + plowed 38 lb P/ac	1.9

Notes:
1. The average of 3 frequency measurements at 1ft. intervals along a 50 ft transect within the tract.
2. Sample depth = top 2 in.
3. Starter fertilizer 5 - 14 - 42 applied at 80 lb / ac.
4. The 2003, 2004 and 2005 manure application rates were 8,500, 9,400 and 10,000 gal/ac, respectively. No records were available for the fall 2002 application which was + 10,200 gal/ac.
5. Corn silage yield = tons dry matter (DM) / acre and corn grain is reported in Bu / ac at 15.5 % moisture.

All tracts were cropped in continuous corn for the entire duration of the study. Two herbicide treatments were completed during the growing season, a pre-emergent application in spring (typically April) and a post-emergent application in early summer (typically June). Liquid dairy manure containing sawdust bedding was applied to the SM treatment each fall after harvest at the rates specified in Table 1 and incorporated by chisel plowing after application. Residue levels were measured every fall after tillage operations using the transect method.

<u>Runoff Sample Collection and Preparation</u>

If runoff samples were present, the water level in each bucket was measured and recorded to the nearest 1/8 inch, and a 60-mL filtered (< 0.45 µm polypropylene syringe filter) sub-sample was collected within 24 h of the runoff event, transported to the laboratory on ice and stored at 4^{o}C for subsequent analysis. The water level in each bucket was used in the calculation of the total storm-event runoff volume, which in-turn was used to determine the storm-event constituent loading. Bucket #1 (B1) was removed from the field, replaced by a clean, empty bucket and transported to the laboratory for reapportioning and subsequent analysis. Buckets #2 (B2) and #3 (B3) were completely mixed in the field and two 1-L sub-samples were collected from each bucket, transported on ice to the laboratory and stored at 4^{o}C for subsequent analysis. Due to the large volume of sample from B1 (maximum 5 gallons), a reapportioning procedure was developed to obtain a representative sub-sample (~ 0.5 gallon) using a Phipps and Bird Jar Tester (Model PB-900; Richmond, VA).

Some storm events (primarily the spring of 2004) produced excessively high sediment loads. This resulted in the filling of B1 and/or B2 with sediments or buckets containing sub-stantially more sediment volume than could be handled by the above procedure. For these cases, sediment core samples were taken from each bucket. Six 1-3/8 inch diameter clear plastic tubes were inserted to the bottom of the bucket for sampling in an evenly spaced pattern. The contents from the six tubes were then transferred to a standard (~ 0.5 gallon) storage container for subsequent analysis.

Chemical Analysis

Prior to analysis, all stored unfiltered samples were mixed and sub-sampled using a Phipps and Bird Jar Tester (Model PB-900; Richmond, VA). Total phosphorus (TP) analysis was run on the unfiltered samples, while dissolved reactive P (DRP), electrical conductivity (EC), pH, and total dissolved P (TDP) were run on filtered samples. The solids analysis included total solids (TS) and total volatile solids (VS). The chemical analyses included: TS, VS, TP, TDP, DRP, EC and pH for B1-B3. The TP mass distribution in five different particle size classes was conducted only for B1. The solids mass in B2 and B3 was typically below the minimum solids mass needed to perform the gravity sedimentation procedure, therefore limiting this analysis only to B1. The analysis suite completed for B1, B2 or B3 was conducted in accordance with Standard Methods (APHA et al., 1995).

Sediment Particle Size by Gravity Settling

Sediments were separated into five different size classes via gravity settling, namely, < 2 µm (clay), 2 to 10 µm (fine silt), 10 to 50 µm (coarse silt), 50 to 500 µm (very fine to medium sand) and > 500 µm (coarse sand) (Toy et al., 2002). Since the focus was on aggregates rather than primary particles, no dispersing agents were used. Initially, each sample was passed through a #35 sieve (0.02 inch) to remove organic crop residue and coarse sand particles. Fractionation into different size classes was achieved using first order settling (Stokes' Law) in a step-wise manner starting with the largest size class first. Stokes' Law was used to determine the settling time for particles of a given diameter over a specified vertical distance. The specific gravity was assumed to be 2.20 g/cm^3 for aggregates greater than 2 µm in diameter and 2.65 g/cm^3 for smaller particles (Alberts et al., 1983, Grande et al., 2005). For the 50- to 500-µm and the 10- to 50-µm fractions, aggregates were allowed to settle in a 1000-mL graduated cylinder for a predetermined time based on fall distance and ambient temperature. The sample temperature was monitored frequently throughout the process. The supernatant was then aspirated and remaining sediments resuspended with MilliQ - grade DI water (Millipore, Billerica, MA) three times for each size class. The process of repeated washing and settling was used to maximize recovery and eliminate particles outside of the desired size range (Alberts and Moldenhauer, 1981; Alberts et al., 1983). The 2- to 10-µm fraction was separated initially by settling followed by resuspention and centrifugation (800 rpm for 7 min). The remaining supernatant contained only particles < 2 µm (clay-sized) in diameter. Once the sediments had been separated by size class, each suspension containing aggregates of a certain size class was placed in a 105^{o}C drying oven for at least 24 h. After drying, each fraction was weighed, scraped from its container and stored in a sealed vial for subsequent TP analysis.

Results and Discussion

The monthly precipitation totals for 2003 to 2005 from the field station and the Arlington Agricultural Research Station rain gauge are shown in Table 2 along with their departures from the 1971-2000 normals. There were 14 runoff producing rainfall events monitored by bulk sampling during 2004. A runoff event was defined as a rainfall that produced sufficient runoff volume to fill bucket number 1 (B1) (minimum volume = 5 gallons).

Table 2. Monthly precipitation totals and departures from normal.

	Monthly Precipitation Totals and Departures from Normal (in)												
Year	**Jan ***	**Feb ***	**Mar ***	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec ***	**Total**
2003	**0.43**	**0.18**	**1.41**	2.01	3.79	2.56	2.69	0.45	4.26	1.00	5.80	**2.08**	**26.66**
Departure	-0.65	-0.98	-0.58	-1.23	0.37	-1.48	-1.17	-3.79	0.62	-1.43	3.42	0.75	-6.15
2004	**0.28**	**1.20**	**2.66**	0.79	8.68	3.29	3.08	2.46	0.77	2.32	1.21	**1.64**	**28.38**
Departure	-0.80	0.04	0.67	-2.45	5.26	-0.75	-0.78	-1.78	-2.87	-0.11	-1.17	0.31	-4.43
2005	**1.45**	**1.15**	**1.81**	0.65	2.13	1.15	3.34	2.32	3.38	0.30	3.74	**0.95**	**22.37**
Departure	0.37	-0.01	-0.18	-2.59	-1.29	-2.89	-0.52	-1.92	-0.26	-2.13	1.36	-0.38	-10.44
Normal	**1.08**	**1.16**	**1.99**	**3.24**	**3.42**	**4.04**	**3.86**	**4.24**	**3.64**	**2.43**	**2.38**	**1.33**	**32.81**

*** Data in bold are from the Arlington Agricultural Research Station.**

Of the runoff-producing rainfall events monitored during the FF period, the median rainfall depth per event was 0.62 in. The median duration for a rainfall event was 8 hours (range 1-32 h) and the median event intensity was 0.09 inch/h. Precipitation during the study period was generally below average annual values, but there were periods of abnormally high rainfall such as during spring 2004. As shown in 21, the 2004 total annual precipitation was below normal but included the record setting high rainfall in May. The monthly total precipitation in May 2004 was 5.26 in above normal, making it the wettest May in Wisconsin history according to records maintained by the Wisconsin State Climatology office (Anderson, 2006). During May, June, and July of 2004, the frequency of occurrence of runoff events was every 5, 6 and 8 days, respectively.

Runoff Volume and Sediment Losses

The largest runoff event occurred on May 22-23, 2004 and the runoff volume and coefficient were significantly higher for all sites from these events when compared to other events that occurred during the study. A disproportionately large fraction of the 2004 FF period runoff volume was generated by rainfall events during May and June. For the CG, CS and SM sites this comprised 98, 93 and 93%, respectively. Statistical analysis of the median runoff coefficients for the three sites indicated that the CG treatment (median runoff coefficient = 0.04) differed significantly ($p < 0.01$) from the CS (0.13) and SM (0.14) treatments, which were similar. Increased residue cover creates ponding and delays surface crust formation, thus increasing infiltration and decreasing runoff volume.

For rainfall-runoff events, a combination of energy available in raindrop impact and shear stress in flowing water dictate the extent of soil detachment and sediment transport. Crop canopy and residue both play an important role in reducing rainfall erosivity by intercepting rainfall and retarding overland flow, thereby decreasing soil loss.

The majority of the specific water quality constituent values in Table 3 for the CG treatment were less than those for CS, while CS and SM had levels similar to each other. The only exception to this was the percent VS values for which the CG treatment was greater. This is not surprising considering that the percent VS values represent the sediment OM fraction and the CG grain treatment had the highest residue levels of the three treatments. These results suggest that the presence of residue significantly reduced soil loss which, in turn, reduced TP export given the strong relationship ($r^2 = 0.97$) between TS and TP losses (Fig. 1). The majority of the P

Table 3. Comparison of runoff constituents among sites for the frost-free period, 2004.

Parameter	Comparison of Median Values	Parameter	Comparison of Median Values
TS EMC (mg/L)	AR1 < AR2 = AR3	**Percent VS**	AR1 > AR3 > AR2
VS EMC (mg/L)	AR1 < AR2 = AR3	**TP EMC (mg/L)**	AR1 < AR2 = AR3
TS Load (lb/ac)	AR1< AR2 = AR3	**DRP EMC (mg/L)**	AR1 < AR2 = AR3
VS Load (lb/ac)	AR1< AR2 = AR3	**DRP Load (lb/ac)**	AR1 < AR2 = AR3
TP Load (lb/ac)	AR1< AR2 = AR3	**TDP Load (lb/ac)**	AR1 < AR2 = AR3

Note : All comparisons were significant at the 0.01 probability level.

loss was found to occur in the particulate-bound form. The close relationship between TP and soil loss has been reported in several previous studies as well (Alberts and Moldenhauer, 1981; Sharpley et al., 1992; Gburek et al., 2005). As the storm-event TP and TS load plots show (Fig. 2 and 3), the within-site variability was greatest for the CS sites.

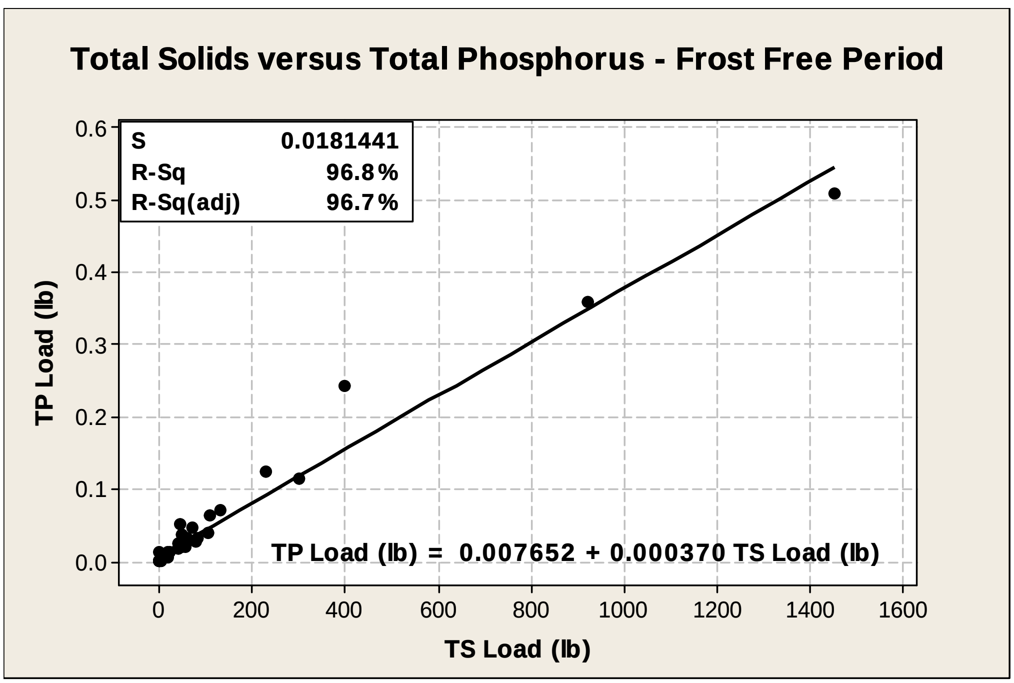


Figure 1. Sediment (TS) versus total phosphorus (TP) loss by tillage type.

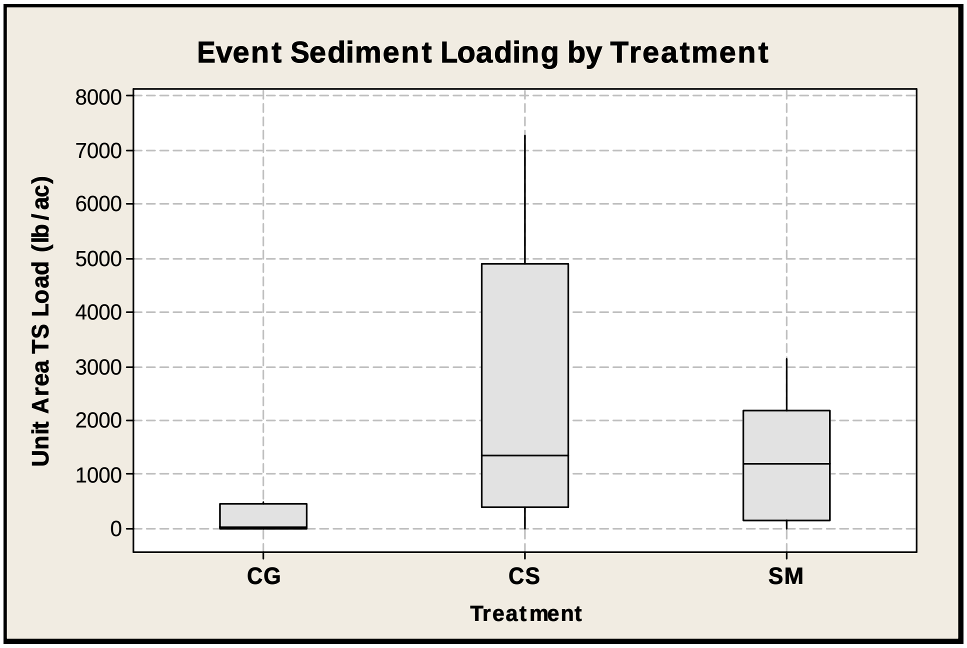


Figure 2. Unit area sediment load by tillage type.

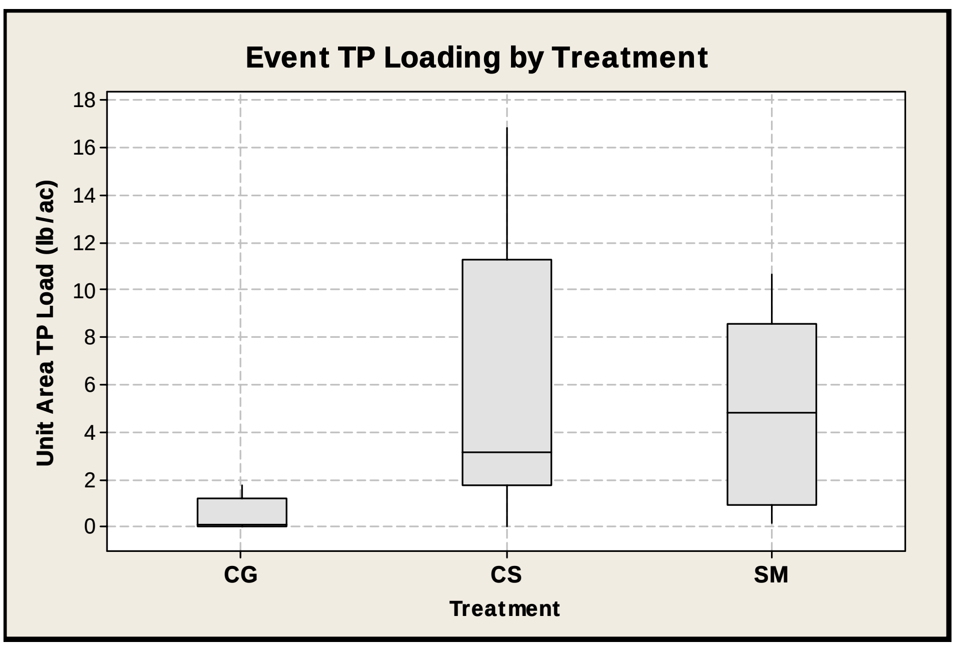


Figure 3. Unit area total phosphorus (TP) export by tillage type.

In Figures 2 and 3, the top and bottom of the boxes are the 75th and 25th percentiles, respectively. The horizontal line within each box is the median, while the extents of the vertical lines are the maximum and minimum values for each treatment. Data from the extreme outlier storm events (May 21 and 23) have been omitted to better illustrate the relationship between treatments under more typical conditions.

<u>Sediment Phosphorus Mass and Particle Size</u>

The gravity settling results are summarized by sediment particle size class in Table 4. The data include the TP concentration (mg/kg), the fraction of TP mass by particle size and the cumulative TP mass by particle-size. The TP mass by size fraction did not differ among treatments across the different particle size classes during the FF period nor were there significant differences in P mass among particle size fractions between sites when the FM and FF data were combined ($p < 0.05$). It is interesting to note that the median TP concentration in the < 2 µm particle size range for the FM (2,140 mg/kg) is greater than that of the FF (1,670 mg/kg) period. This is likely the result of the preferential transport of enriched fine particles and OM by the low flow velocities produced by the snowmelt. The highest sediment TP concentration for both the FM and FF periods was found in the smallest (< 2 and 2 to 10 µm) sediment particle size classes. Similar results were obtained by Dong et al. (1983), Grande et al. (2005), and Sharpley (1980). Because of their size, the < 2 and 2 to 10 µm size particles have high specific surface area that favors greater chemical accumulation including P (Dong et al., 1983; Pierzynski et al., 1990).

Table 4. Gravity settling values for percent TS and TP concentration for five sediment particle size classes from the frost melt and frost-free periods.

	Particle Size (µm)				
	<2	2 - 10	10 - 50	50 - 500	> 500
FM Period, (N = 10)					
Median TS (%)	4.10	8.55	30.1	50.9	4.45
Range *	3.00 - 6.08	7.28 - 18.5	23.8 - 34.5	37.4 - 56.3	1.81 - 7.38
Median TP (mg/kg)	2140	1080	498	571	717
Range *	1,800 - 2,490	956 - 1,310	404 - 612	472 - 677	621 - 908
FF Period, (N = 36)					
Median TS (%)	3.00	10.7	23.0	53.4	7.31
Range *	1.89 - 4.17	8.21 - 12.2	19.7 - 30.1	41.6 - 53.4	4.30 - 13.0
Median TP (mg/kg)	1670	1140	483	367	514
Range *	1,550 - 2,080	992 - 1,310	417 - 549	297 - 450	428 - 633
Percent P mass	11	22.4	23.3	35.8	7.6
Cumulative P Mass	11	33	57	93	100

* Range equals the 1st and 3rd quartile values.

The absence of a significant effect on P-mass distribution in different size classes due to differences in management (i.e., corn harvesting practices and/or manure management) suggests that the particle size-P mass relationship may be unique for a given soil type, clay content and mineralogy, when a narrow range in soil OM exists. As shown in Table 4, 57% of the P mass was associated with particles < 50 µm in size. The small (< 50 µm) size particles also have the greatest transport potential. These results suggest that if reside removal is not managed, excessive soil loss could occur, in-turn adversely impact water quality and soil productivity. As discussed in Wilhelm et al. (2004), residue removal rates must be must be carefully managed to minimize water quality impacts and ensure sustainable soil productivity.

Conclusions

The presence of residue was found to significantly reduce soil loss which, in turn, reduced TP export. The transport of particulate-bound P was the principal mechanism for P export from conservation tillage corn fields. The transport potential of sediment particles is directly influenced by particle size and density suggesting that smaller, less dense particles have greater transported potential. These results indicated that 57% of the P mass was associated with particles < 50 µm (clay and silt) size. The increased transport of fine P enriched particles increases the potential for downstream water quality degradation. The demand for bio-based fuel production will likely increase the production of corn and other row crops. The implementation of sound land management practices will, therefore, be essential to minimize water quality degradation and maintain soil health and productivity.

References

Alberts, E.E, and W.C. Moldenhauer. 1981. Nitrogen and phosphorus transport by eroded soil aggregates. Soil Sci. Soc. Am. J. 45:391-396.

Alberts, E.E., R.C. Wendt, and R.F. Piest. 1983. Physical and chemical properties of eroded soil aggregates. Trans. ASAE 26:465-471.

American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF). 1995. Standard methods for the examination of water and wastewater. APHA, Washington, DC.

Anderson, L.J. 2006. "Citation for May record precip." Email to John Panuska. 22 May 2006.

Dong, A., G.V. Simsiman, and G. Chesters. 1983. Particle-size distribution and phosphorus levels in soil, sediment, and urban dust and dirt samples from the Menomonee River watershed, Wisconsin, U.S.A. Water Res. 17:569-577.

Gburek, W.J., E. Barberis, P.M. Haygarth, B. Kronvang, and C. Stamm. 2005. Phosphorus mobility in the landscape. p. 941-979. *In* Phosphorus: agriculture and the environment. Agron. Monogr. no.46. ASA, CSSA, SSSA, Madison, WI.

Gillingham, A.G., and B.S. Thorrold. 2000. A review of New Zealand research measuring phosphorus in runoff from pastures. J. Environ. Qual. 29:88-96.

Ginting, D., J.F. Moncrief, S.C. Gupta, and S.D Evans. 1998. Interaction between manure and tillage system on phosphorus uptake and runoff losses. J. Environ. Qual. 27:1403-1410.

Grande, J.D., K.G. Karthikeyan, P.S. Miller and J.M. Powell. 2005. Residue level and manure application timing effects on runoff and sediment losses. J.Environ. Qual. 34:1337-1346.

Logan, T.J. 1980. The role of soil and sediment chemistry in modeling nonpoint sources of phosphorus. *In* M.R. Overcash and J.M Davidson (ed.) Environmental impact of nonpoint source pollution. Ann Arbor Science, Ann Arbor, MI.

Logan, T.J. 1982. Mechanisms for release of sediment-bound phosphate to water and effects of agricultural land management of fluvial transport of particulate and dissolved phosphate. Hydrobiologia 91/92:519-530.

Parry, R. 1998. Agricultural phosphorus and water quality: a U.S. environmental protection agency perspective. J. Environ. Qual. 27:258-261.

Pierzynski, G.M., T.J. Logan, S.J. Traina and J.M Bigham. 1990. Phosphorus chemistry and mineralogy in excessively fertilized soils: Quantitative analysis of phosphorus-rich particles. Soil Sci. Soc.Am. J. 54:1576-1583.

Sharpley, A.N. 1980. The enrichment of soil phosphorus in runoff sediments. J. Environ. Qual. 9:521-526.

Sharpley, A.N., S.J. Smith, O.R. Jones, W.A. Berg, and G.A. Coleman. 1992. The transport of bioavailable phosphorus in agricultural runoff. J. Environ. Qual. 21:30-35.

Toy, T.J., G.R. Foster, and K.G. Renard. 2002. Soil erosion: processes, measurement and control. Wiley and Sons Pub., New York. 338 p.

U.S. Environmental Protection Agency (USEPA). 1996. Environmental indicators of water quality in the United States. EPA 841-R-96-002. Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1995. National water quality inventory: 1994 Report to Congress. EPA 841-R-95-005. Office of Water. USEPA, Washington, DC.

Uusitalo, R., E. Turtola,T. Kauppila, and T. Lilja. 2001. Particulate phosphorus and sediment in surface runoff and drain flow from clayey soils. J. Environ. Qual. 30:589-595.

Wilhelm, W.W., J.M.F. Johnson, J.L. Hatfield, W.B. Vorhees, and D.R. Linden. 2004. Crop and soil productivity responses to corn removal: A literature review. Agron. J. 96:1-17.

CRP TO CROPLAND: POTENTIAL LOSS OF CRP SOIL QUALITY BENEFITS

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Introduction and Background

The Conservation Reserve Program (CRP) was implemented in 1985 to protect environmentally fragile or highly erosive crop land from degradation and carbon loss to the atmosphere (CAST, 1992). Currently there are approximately 36 million acres, 8% of the nation's cropland, in the CRP program (FSA, 2006). Ethanol production, and the subsequent need for corn for the ethanol industry, may take land from CRP programs, potentially threatening the beneficial effects of the CRP program on soil quality. Here I'll present possible changes in soil quality resulting from putting CRP land into production.

Current ethanol production is approximately 4.4 billion gallons/year and is expected to increase to 6.5 billion gallons/year by the end of 2007 (Baker and Zahniser, 2006); an increase requiring 2.6 billion additional bushels/year of corn or 17.3 million acres of corn (at 150 bushels per acre). The competition for corn will naturally drive up corn prices, outweighing CRP payments, and provide incentive for producers to take land out of the CRP program. Each year over the next several years, 10 to 15% of CRP contracts are up for renewal, potentially 55% or approximately 20 million acres of CRP land could be lost (FSA, 2006) (Fig. 1). With this proportion of conservation land lost from the CRP program, it's important to assess the consequences for soil quality.

The definition of soil quality changes based on differing perspectives. One perspective on management for soil quality is management or "farming" for a healthy soil community. Some common measures of soil quality are percent organic matter, amount of organic carbon, amount of total carbon and nitrogen, amounts of microbial carbon and nitrogen, water content, infiltration rates, and aggregate stability (strength of the soil structure). Symptoms of a 'nonquality' soil or poor soil management could be erosion, nutrient leaching, poor water infiltration, or poor aggregate stability. What is behind these measures of soil quality? What builds soil quality? The answer to these questions is the growth and activity of soil organisms (Balser, 2004; Sylvia et al., 2005). Macrofauna such as moles and earthworms physically degrade and move soil and plant residues. This physical degradation increases surface area and ease of chemical degradation for smaller organisms such as bacteria and fungi to further degrade plant residues eventually into organic matter in the soil. Another physical aspect of microbial growth and organic matter is that organic matter and microbial residues act to "glue" soil particles together to create more stable aggregates. Ribbon-like fungal hyphae of also act to physically bind particles together. The resultant aggregation and aggregate stability from organic matter and fungal growth in turn act to reduce erosion, improve water infiltration, and feedback to improve the habitat for microbial growth. Another positive benefit of organic matter for soil structure and soil habitat is that, like a sponge, organic matter helps to hold nutrients (improved cation exchange capacity) and water.

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CRP and Soil Quality

Current evidence from a large body of research suggests that the CRP program is successful at improving soil quality in terms of organic matter (measured as organic carbon), microbial biomass, and soil physical characteristics (Karlen et al., 1998). Physically, soil bulk density has been shown to decrease in CRP lands (Baer et al., 2002) as well as increased resistance to erosion (Huang et al., 2002). A detailed look at these benefits will set the stage for examining how CRP benefits are lost when land is removed from the program.

Soil organic carbon (SOC) is a common measure of soil quality, as discussed in the introduction, and is a good index of the amount of organic matter in the soil (more organic carbon means more organic matter). SOC increases significantly at CRP sites versus crop land (Gebhart et al., 1994; Follett, 1997; Reeder et al., 1998; Follet et al., 2001; Lal et al., 2003), potentially sequestering 535 to 800 lb C/acre/yr (Follet et al., 2001), although some studies have shown little or no statistically significant increase in SOC (Huggins et al., 1997; Staben et al., 1997; Robles and Burke, 1998; Karlen et al., 1999; Huang et al., 2002). Microbial biomass and residues also increase in CRP versus cropland (Follett, 1998; Huggins et al., 1998; Karlen et al., 1998; Karlen et al., 1999; Amelung et al., 2001; Baer et al., 2002). Microbial activity, measured as carbon mineralization (the conversion of organic carbon into carbon dioxide through respiration) or nitrogen mineralization (the conversion of organic nitrogen such as protein into nitrate or ammonium), are also higher in CRP grasslands versus cropland (Schumaker et al., 1995; Reeder et al., 1998; Robles and Burke, 1998; Karlen et al., 1999; Baer et al., 2002).

Time could be a major factor in the level of SOC accumulation in CRP lands, as suggested by evidence that even when SOC is higher in CRP vs. cropland, SOC (Gebhart et al., 1994; Huggins et al., 1998) and microbial biomass (Amelung et al., 2001) are still significantly lower in CRP land compared to native grasslands. In addition there is evidence that SOC accumulation increases in CRP and fallow land over time (Burke et al., 1995; Baer et al., 2000; Baer et al., 2002; Murphy et al., 2006) suggesting that long term CRP enrollment may be needed to increase SOC back to native levels. Soil characteristics such as topography, climate, and texture may influence the degree to which organic carbon is sequestered in CRP lands (Follett 1998); for instance Reeder et al. (1998) found less relative carbon sequestration on clay loam vs. sandy loam soils, and Staben et al. (1997) found less accumulation on semi-arid lands that may be slower to accumulate organic matter. A third cause of variance in carbon sequestration on CRP versus croplands is microbial activity. An increase in carbon mineralization (conversion of organic carbon into carbon dioxide from microbial activity) as suggested by many studies may be the cause of low overall increase in organic carbon at some CRP sites (Staben et al., 1997; Robles and Burke, 1998; Karlen et al., 1999).

Another major measure of soil quality is the amount of nitrogen and microbial nitrogen transformations. Similar to organic carbon, total organic nitrogen is higher in CRP than cropland (Staben et al., 1997; Reeder et al., 1998), although the significance of this increase varies and is sometimes less significant statistically (Robles and Burke 1998). Inorganic nitrogen may be lower in CRP land (Baer et al., 2000; Baer et al., 2002), suggesting that microbial and plant efficiency at using and recycling nitrogen are higher in CRP lands, thus indicating a healthy soil community.

Removal of Land from CRP

There is a smaller but convincing body of research on the effects on soil quality on expired CRP land, all showing that soil quality gains from CRP are quickly lost. (Gilley and Doran 1997, Gilley et al. 1997, Gewin et al., 1999; Gilley et al. 2001; Dao et al. 2002). Gilley and Doran

(1997) found that 9 months after tilling CRP land in northern Mississippi, sediment loss had substantially increased and soil quality indicators including bulk density, total carbon, and microbial C and N decreased to levels similar to that of long-term cropped land. Similar results were reported for southwest Iowa (Gilley et al., 1997), Nebraska, South Dakota, and another Mississippi site (Gilley et al., 2001). Semi-arid Oklahoma soils show a similar increase in erosion when taken out of CRP management, but there is a smaller loss of organic carbon (this site had also shown smaller increases overall on CRP land compared to cropland) (Dao et al., 2002). At four sites in Washington State, Gewin et al. (1999) found that although the sites all had unique responses to being taken out of CRP management, all the sites quickly lost organic carbon.

Management to Preserve the Benefits of the CRP on Soil Quality

For the preservation of soil quality on expired CRP land, there is strong evidence that no-till should be used. Several studies have reported less SOC loss or degradation of soil quality when CRP land is cropped with no-till management (Shumacher et al., 1995; Karlen et al. 1996; Gilley and Doran 1997; Gilley et al. 1997; Follett ,1998; Huggins et al., 1998; Gewin et al., 1999; Dao et al., 2001) (although it may be difficult to fully keep SOC at CRP levels when returning the sites to cropland (Huggins et al., 1998). For instance, Gewin et al. (1999) found the least organic carbon lost in spring direct seed (no till) treatments as opposed to other tillage treatments.

Conclusions

It is well established that the CRP program enhances soil quality, although to varying degrees that may be due to time in the program, soil type, or microbial activity. The benefit of CRP management for soil quality also increases over time, and may take up to 50 years to reach native grassland levels of organic carbon and microbial biomass. Although it takes time and investment to improve soil quality parameters through the CRP program, the benefits could be quickly lost depending on the management practices. For instance, Gilley and Doran (1997) found that in 9 months, organic carbon levels had decreased to that of pre-CRP levels. Given these considerations, the best practice in easily degraded CRP lands is to keep them planted with perennial vegetation such as in CRP. If necessary to put these lands back into crop production, low disturbance tillage such as no-till should be employed.

References

Amelung, W., J.M. Kimble, S. Samson-Liebig, and R.F. Follett. 2001. Restoration of microbial residues in soils of the conservation reserve program. Soil Sci. Soc. Am. J. 65:1704-1709.

Baer, S., C.W. Rice, and J.M. Blair. 2000. Assessment of soil quality in fields with short and long term enrollment in the CRP. J. Soil Water Conserv. 55:142-146.

Baer, S., D.J. Kitchen, J.M. Blair, and C.W. Rice. 2002. Changes in ecosystem structure and function along a chronosequence of restored grasslands. Ecol. Appl. 216:1688-1701.

Baker, A., and S. Zahniser. 2006. Ethanol reshapes the corn market. Amber Waves 4: 30-35 [online] Available at http://www.ers.usda.gov/AmberWaves/April06/Features/ Ethanol.htm. {Verified December 11, 2006}.

Balser, T.C. 2004. Humification. *In* D. Hillel et al. (ed.) Encyclopedia of soils in the environment. Elsevier, New York..

Council for Agricultural Science and Technology (CAST). 1992. Preparing USDA agriculture for global change. Task Force Rep. no. 199. CAST, Ames, IA.

Dao, T.H., J.H. Steigler, J.C. Banks, L.B. Boerngen, and B. Adams. 2002. Post-contract land use effects of soil carbon and nitrogen in conservation reserve grasslands. Agron. J. 94:146-152.

Farm Service Agency (FSA). 2006. Summary of active and expiring CRP cropland acres by state [Online report]. Available at http://content.fsa.usda.gov/crpstorpt/11Approved/rmepegg/MEPEGGR1.HTM. {Verified December 11, 2006}.

Follett, R.F. 1998. CRP and microbial biomass dynamics in temperate climates. p. 305-322. *In* R. Lal et al. (ed.) Management of carbon sequestration in soil. CRC Press, New York.

Follet, R.F., E. Samson-Liebig, J.M. Kimble, E.G. Prossner, and S. Waltman. 2001. Carbon sequestration under CRP in the historic grassland soils of the US. p. 27-40. *In* R. Lal (ed.) Soil carbon sequestration and the greenhouse effect. Soil Sci. Soc. Am. Special Pub. no. 57, Madison WI.

Gebhart, D.L., H.B. Johnson, H.S. Mayeux, and H.W. Polley. 1994. The CRP increases soil organic carbon. J. Soil Water Conserv. 49:488.

Gewin, V.L., A.C. Kennedy, R. Veseth, and B.C. Miller 1999 Soil quality changes in eastern Washington with conservation reserve program (CRP) take-out. J. Soil Water Conserv. 54:432-438.

Gilley, J.E., and J.W. Doran.1997. Tillage effects on soil erosion potential and soil quality of a former conservation reserve program site. J. Soil Water Conserv. 52:184-188.

Gilley, J.E., J.W. Doran, and B. Eghball. 2001. Tillage and fallow effects on selected soil quality characteristics of former conservation reserve program sites. J. Soil Water Conserv. 56:126-132.

Gilley, J.E., J.W. Doran, D.L. Karlen, and T.C. Kaspar. 1997. Runoff, erosion, and soil quality characteristics of a former conservation reserve program site. J. Soil Water Conserv. 52:189-193.

Huang, X., E.L. Skidmore, and G.L. Tibke. 2002. Soil quality of two Kansas soils as influenced by the conservation reserve program. J. Soil Water Conserv. 57:344-350.

Huggins, D.R., D.L. Allan, J.C. Gardner, D.L. Karlen, D.F. Bezdicek, M.J. Rosek, M.J. Alms, M. Flock, B.S. Miller, and M.L. Staben. 1998. Enhancing carbon sequestration in CRP managed land. p. 305-322. *In* R. Lal et al. (ed.) Management of carbon sequestration in soil. CRC Press, New York.

Karlen, D.L., J.C. Gardner, and M.J. Rosek. 1998. A soil quality framework for evaluating the impact of CRP. J. Prod. Agric. 11:56-60.

Karlen, D.L., T.B. Parkin, and N.S. Eash. 1996. Use of soil quality indicators to evaluate conservation reserve program sites in Iowa. p. 345-355. *In* J.W. Doran and A.J. Jones (ed.) Methods of assessing soil quality. {MORE NEEDED}

Karlen, D.L., M.J. Rosek, J.C. Gardner, D.L. Allan, M.J. Alms, D.F. Bezdicek, M. Flock, D.R. Huggins, B.S. Miller, and M.L. Staben. 1999. Conservation reserve program effects on soil quality indicators. J. Soil Water Conserv. 54:439-444

Lal, R., R.F. Follett, and J.M. Kimble. 2003. Achieving soil carbon sequestration in the United States: a challenge to the policy makers. Soil Sci. 168:827-845.

Murphy, C.A., B.L. Foster, M.E. Ramspott, and K.P. Price. 2006. Effects of cultivation history and current grassland management on soil quality in northeastern Kansas. J. Soil Water Conserv. 61:75-84.

Reeder, J.D., G.E. Schuman, and R.A. Bowman. 1998. Soil C and N changes on conser-vation reserve program lands in the central Great Plains. Soil Tillage Res. 47:339-349.

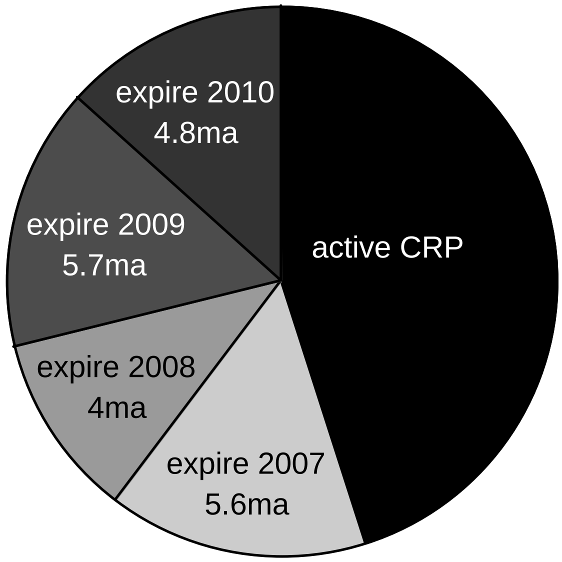
Robles M, and IC Burke 1998 Soil organic matter recovery on conservation reserve program fields in southeastern Wyoming. Soil Sci. Soc. Am. J. 62:725-730.

Schumache,r T.E., M.L. Lindstrom, M.L. Blecha, N.P. Cogo, D.E. Clay, and B.H. Bleakley.1995. Soil management after CRP contracts expire. Trans. ASAE 3:239-242.

Staben, M.L., D.F. Bezicek, J.L. Smith, and M.F. Fauci. 1997. Assessment of soil quality in conservation reserve program and wheat-fallow soils. Soil Sci. Soc. Am. J. 61:124-130.

Sylvia, D.M. 2005. Principles and applications of soil microbiology. 2nd ed. Prentice, Upper Saddle River, NJ.

Figure 1: National CRP acreage potentially expiring by 2010
Current active CRP= 36.7ma nationally



Adapted from FSA (2006)

Figure 2. Increase of organic carbon in CRP vs. cropland

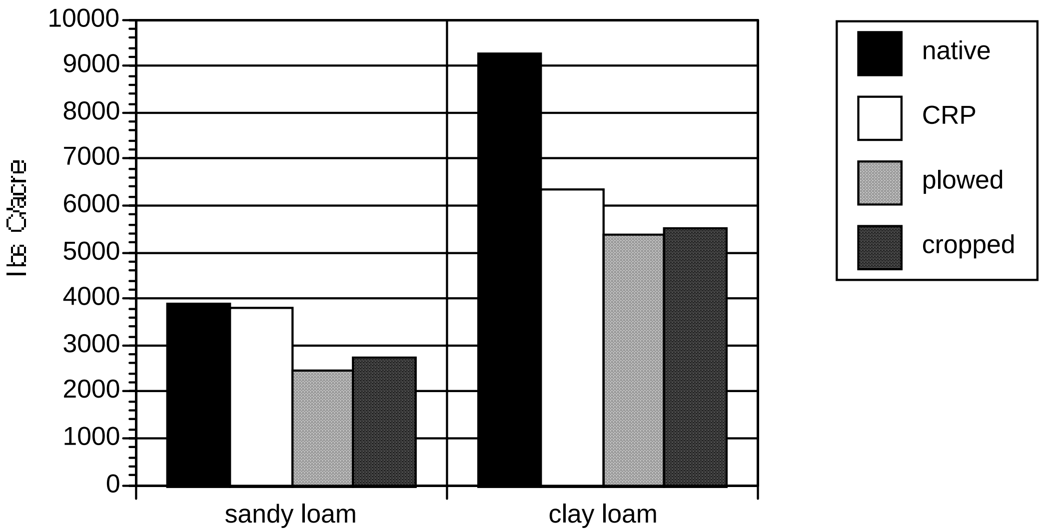


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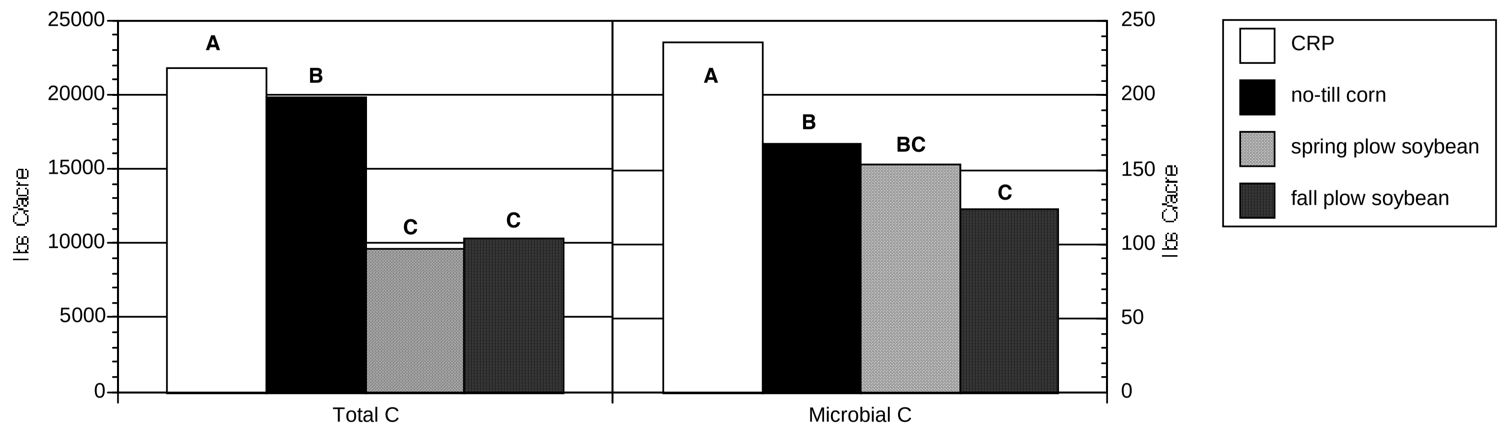
Figure 3. Tillage effects on soil and microbial carbon after CRP removal



Adapted from Gilley et al. (1997)

TIPS FOR OPTIMUM WHEAT PRODUCTION

John Gaska [1/]

Introduction

Winter wheat acreage in Wisconsin has been steadily increasing since the early 1970s indicating an interest by existing growers to either increase their present acreage or adding new growers willing to try winter wheat (Fig. 1).

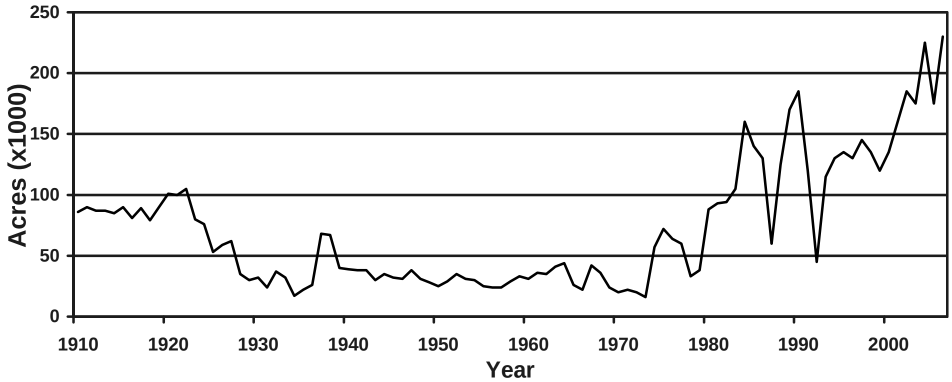


Fig. 1. Historical harvested acreage of winter wheat in Wisconsin. 1910 to 2006. (USDA-NASS, 2006).

Winter wheat yields in Wisconsin have been increasing at about 0.7 bu/a/yr since the early 1940s, indicating advancements in both wheat genetic yield potential and better management practices (Fig. 2).

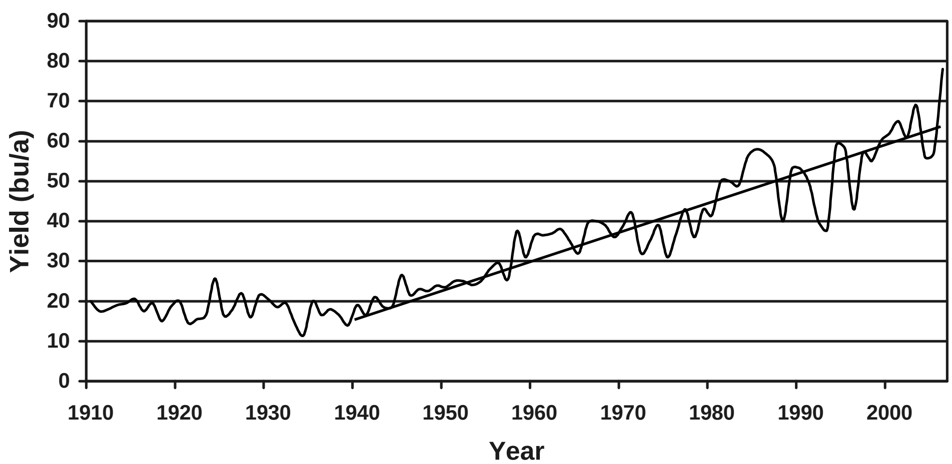


Fig. 2. Historical yield of winter wheat in Wisconsin. 1910 to 2006. (USDA-NASS, 2006).

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Separating any genetic advancements from environmental and management factors is often difficult. Wisconsin growers fortunately can select from a large list of varieties (Kaeppler et al., 2006) and manage them for high yields. Economic factors and the cropping system needs of Wisconsin farmers have led growers to choose wheat as a viable rotational crop. Winter wheat requires high management for optimum yields, similar to the management that growers invest in growing corn, soybean, or hay crops. Winter wheat is a good fit in Wisconsin with existing conservation tillage systems. It can be successfully planted and grown in existing crop residue, especially soybean. Wheat is a good competitor against weeds, keeping herbicide costs low. In addition, it has a high grain and straw yield potential, providing two sources of income from a single crop.

Intensive Wheat Management

Over the years, many authors have suggested techniques for improving wheat yields through so called "intensive wheat management" plans. Oplinger et al. (1985) outlined 15 steps for maximum wheat yields in Wisconsin. Bitzer and Herbek (1996) listed 18 steps for Kentucky growers to follow to increase their yields. Alley et al. (1993) outlined 8 steps to intensively manage soft red winter wheat in Virginia. Some grain merchandisers also offer suggestions for intensive wheat management to encourage and reward the production of high quality wheat with price premiums (Siemer, 2006).

Review of these and several other guides for intensive wheat management reveal many common recommendations, regardless of geographical location. Commonly, the first step in these guides to high wheat yields is the understanding of wheat growth and development. Following the understanding of wheat plant growth, most guides provide guidance with fertility, seedbed preparation, planting date and rate, weed and disease control, and optimal harvesting and marketing advice. We will pick out several of these and look closer at how Wisconsin growers can optimize wheat production.

Wheat Growth and Development

Growers planning for a successful wheat growing program need to understand how the plant grows and develops. Many management decisions are based on wheat growth stage and wheat, like corn and soybeans, responds to inputs applied at the correct stage of growth. The Feekes (Large, 1954) (Fig. 3) and the Zadoks (Zadoks et al., 1974) scales are commonly used to describe the growth of wheat. The Feekes scale uses a 1 to 11 scale while the Zadoks scale starts at 0 and ends at 100. The Feekes scale is more popular. However, either staging system will provide accurate growth stage information. The life cycle of wheat can be summarized by dividing it into two main stages, with anthesis marking the transition between the stages. In the first stage, vegetative growth is followed by seed initiation and development. This stage determines the final yield potential of the crop. The second stage is the grain filling period in which the potential yield developed in the first phase is realized. Optimum climatic conditions and proper management inputs during this period are very critical. Relevant growth stages will be indicated in the following discussion.

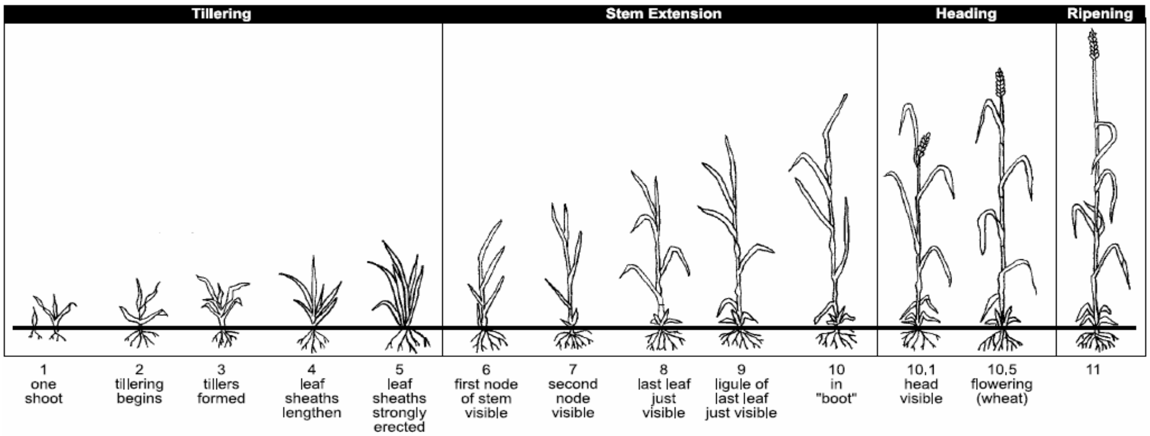

Fig. 3. The Feekes scale of wheat development.

Nitrogen Management

Nitrogen is the plant nutrient that usually limits wheat yields if it not present in the right amounts at the right time. Current nitrogen fertilizer recommendations for Wisconsin can be found in Laboski et al. (2006). Generally, 70 lb/a of N is adequate for soils with 2.0 to 9.9% organic matter. Applying too much N fertilizer can have detrimental effects on yield. Excessive N fertilization encourages excess vegetative growth, which increases the possibility of lodging, making harvest more difficult and also increases disease potential due to a dense canopy. Nitrogen credit for any applied manure needs to considered as well as an N credit of 40 lb/a for wheat following soybean.

Recent research (Lauer and Bundy, unpublished, 2006) at Arlington Ag Research Station focused on optimum N rates for wheat following three crop/management scenarios. Nitrogen rates of 0 to 125 lb/a were spring-applied to wheat in a no-tillage system. In 2005, wheat yields did not respond to N applications over 50 lb/a, and results from 2006 indicated no response over 25 lb/a (Table 1). Nitrogen applications to wheat should be made in early spring at Feekes GS3 to GS5. Applying N on slightly frozen ground in mid to late April in southern WI minimizes wheel traffic problems and meets the early season N needs of wheat. If stands are thin, tillering can be promoted with additional N applications.

Seeding Wheat

Winter wheat in Wisconsin is generally planted from mid-September to early October. Generally wheat yields are highest when it is planted the last 2 weeks of September and before the October 5 in southern Wisconsin. Too early (early September) planting exposes the wheat to possible infection from barley yellow dwarf virus which is carried by aphids. Too late planting does not allow the plant to establish roots and gain the winterhardiness necessary to survive the winter. Also, wheat needs a vernalization period to induce reproductive growth in the following spring and summer. Low temperature damage to the crown and suffocation of the plant are the two most common causes of wheat winterkill. Wheat is most susceptible to winter injury or death in early spring if the crown of the plant is smothered or not protected when wide temperature fluctuations occur and soil repeatedly freezes and thaws. The risk of winter injury or death is minimized when wheat is planted into standing stubble, in moist, weed free, fertile soils using a no-till drill within the recommending planting date range.

Table 1. Effect of previous crop and N rate on no-till wheat grain yield.
Arlington, WI. 2005 and 2006.

Year	N rate	Previous Crop Soybean	Corn silage	Corn grain	Mean
	lb/a	---------------- bu/a ----------------			
2005	0	65	48	40	51 c
	25	72	56	52	60 b
	50	74	66	52	64 ab
	75	71	67	57	65 a
	100	77	67	53	66 a
	125	73	68	53	65 a
	2005 mean	72 a	62 b	51 c	
2006	0	70	61	65	65 c
	25	74	74	64	70 ab
	50	76	73	63	71 ab
	75	77	72	74	74 a
	100	77	74	68	73 a
	125	71	65	62	66 bc
	2006 mean	74 a	70 ab	66 b	

Seeding depth of wheat is an important consideration. Seeding too deep results in delayed emergence, which increases the potential for winterkill. Deep seeded wheat does not benefit from soil surface warming during the day, and is further delayed by cool night temperatures. Optimal seeding depth for wheat is 1 inch.

Wheat seeding rates recommendations have varied widely both in amount to seed and in units for measuring seed planted per area. We are recommending a change from using pounds of seed per acre or seeds per square foot to seeds per acre, similar to corn and soybean seeding rate recommendations. Because winter wheat seed size is highly variable, just using a unit like pounds per acre can result in highly variable seeding rates in terms of seeds per acre. Table 2 shows recommended seeding rates for a range of planting dates in Wisconsin. Also shown are spring plant density targets for growers assessing spring stands and over-winter survival.

Tillage and Rotation Considerations

Winter wheat can be established in no-till systems. No-till is especially well suited for planting wheat after soybeans. Accumulations of residue on the soil in a no-till system help protect small seedlings by trapping snow and serving as an insulating blanket. Pay particular attention to spreading residue evenly across the field so that it does not interfere with good seed to soil contact and burn down any existing weeds, especially dandelions and winter annuals prior to planting. Planting winter wheat after corn taken for grain or silage is generally not recommended unless the corn residue is incorporated into the soil. This is because of the risk for head scab, *Fusarium graminearum*, which also causes *Giberella* stalk and ear rot in corn.

Pest Management

Careful observation of the crop through the season will enable you to apply timely pest control when it is necessary. Seed-applied fungicides are typically applied to control seedling blight, loose smut, or bunt. Several fungicide products are currently available to Wisconsin growers (Boerboom et al., 2006). The addition of seed-applied insecticides is primarily used to plants have emerged by vectoring the barley yellow dwarf virus. Winged, infected aphids fly to

Table 2. Winter wheat seeding recommendations and spring plant density targets.

Seeds/acre Million	Seeds/sq ft	Row Width 6	Row Width 7	Row Width 7.5	Spring density	
		Plants per foot row				
0.3	6.9	3	4	4		
0.4	9.2	5	5	6	Minimum spring densities	
0.5	11.5	6	7	7		
0.6	13.8	7	8	9		
0.7	16.1	8	9	10		
0.8	18.4	9	11	11		
0.9	20.7	10	12	13		Seeding Rate for Sept 1 to Sept 15
1.0	23.0	11	13	14	Good spring densities	
1.1	25.3	13	15	16		
1.2	27.5	14	16	17		
1.3	29.8	15	17	19		
1.4	32.1	16	19	20		Seeding Rate for Sept 15 to Oct. 1
1.5	34.4	17	20	22		
1.6	36.7	18	21	23	Excellent spring densities	
1.7	39.0	20	23	24		
1.8	41.3	21	24	26		
1.9	43.6	22	25	27		Seeding Rate for Oct. 1 to Oct 10
2.0	45.9	23	27	29		
2.1	48.2	24	28	30		
2.2	50.5	25	29	32		
2.3	52.8	26	31	33		
2.4	55.1	28	32	34		
2.5	57.4	29	33	36		
2.6	59.7	30	35	37		

these fields and transmit the virus as they feed. Delaying wheat planting into later September control aphids. Aphids, such as the bird cherry-oat aphid, infect winter wheat in the fall after the reduces the opportunity for aphids to feed and transmit the virus. Gaucho 480F (imidacloprid, Gustafson) seed treatment is labeled for the early season control of aphids. Fig. 4 shows results for a seed treatment study at two locations in Indiana during the 2005-2006 growing season. Data from one location indicated no effect from either the fungicide or insecticide seed treatments. At the second location, there was a significant yield increase for a Raxil-Thiram (tebuconazole + thiram, Gustafson) + Gaucho combination treatment. This may indicate that aphids were a significant problem. Data from local sources should also be used in determining whether to use a particular product. Other factors to consider in choosing whether to use a seed pesticide treatment include planting date, seed quality, and cost of the pesticide.

Foliar applied fungicides fit into intensive wheat management systems that use practices such as high N rates, high seeding rates, and high yielding varieties. The primary purpose of applying foliar fungicides is to protect the health of the flag leaf. The flag leaf is the largest leaf on a wheat plant and is the first leaf below the head. The flag leaf contributes up to 85% of the final grain yield due to its size and location on the plant and in the canopy. Grain yield reductions can occur if only 5 to 10% of the area of the flag leaf surface is diseased. Foliar-applied fungicides may provide economical yield increases if:

- Disease is present on the lower leaves
- Humid weather with moderate temperatures are forecast for longer periods
- High yield management practices are employed
- Wheat is planted following wheat
- Varieties planted are susceptible to common leaf diseases

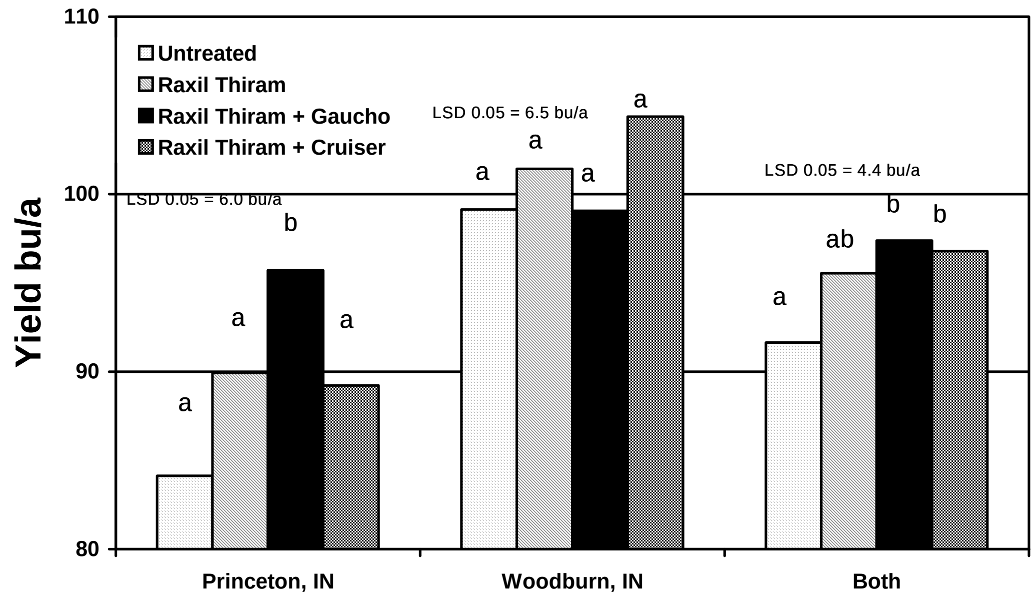

Fig. 4. Effect of fungicide and insecticide seed treatments on winter wheat yields in Indiana. 2006. (Tryon, unpublished data, 2006).

A sound weed control program combines cultural, mechanical and chemical control. Post emergence applied herbicides need to be applied at the correct stage of weed and crop growth and the herbicide should match the weed spectrum present in the field. Growers should be especially careful of applications of 2,4-D and dicamba after jointing because these herbicides can reduce yield or cause blank heads. Certain herbicides can also be applied in liquid fertilizer, but this should only be done if recommended on the herbicide label.

References

Alley, M.M., D.E. Brann, E.L. Stomberg, E.S. Hagood, A. Herbert, E.C. Jones, and W.K. Griffith. 1993. Intensive soft red winter wheat production. p. 424-803. *In* Virginia Tech Cooperative Extension, Blacksburg, VA.

Bitzer, M., and J. Herbek (ed.) 1996. A comprehensive guide to wheat management in Kentucky. ID-125. Univ. of Kentucky College of Agriculture, Lexington, KY.

Boerboom, C.M., E.M. Cullen, R.A. Flashinski, C.R. Grau, B.M. Jensen, and M.J. Renz. 2006. Pest management in Wisconsin field crops-2007. UWEX Pub. A3646. Univ. of Wisconsin-Extension, Madison, WI.

Kaeppler, H.F., J. Mochon, M.J. Martinka, and J.M. Gaska. 2006. Small grain varieties for grain and forage in Wisconsin-2007. UWEX Pub. A3397. Univ. of Wisconsin-Extension, Madison, WI.

Laboski, C.A.M., J.B. Peters, and L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. UWEX Pub. A2809. Univ. of Wisconsin-Extension, Madison, WI.

Large, E.C. 1954. Growth Stages in Cereals. Illustrations of the Feekes Scale. Plant Path. 3:128-129.

Oplinger, E.S., D.W. Wiersma, C.R. Grau, and K.A. Kelling. 1985. Intensive wheat management. UWEX Pub. A3337. Univ. of Wisconsin-Extension, Madison, WI.

Siemer Milling Company. 2006. 2007 Intensive wheat management program [Online]. Available at http://www.siemermilling.com/html/2006_intensive_wheat_managemen.html (accessed 12 Dec 2006). Siemer Milling Co., Teutopolis, IL.

USDA-National Agricultural Statistics Service. 2006. Wisconsin reports and statistics [Online]. Available at http://www.nass.usda.gov/Statistics_by_State/Wisconsin/index.asp#.html (accessed 12 Dec 2006). USDA-NASS, Washington, DC.

Zadoks, J.C., T.T. Chang, and C.F. Konzak. 1974. A decimal code for growth stages of cereals. Weed Res. 14:415-21.

Additional Sources of Information on Winter Wheat Production

Illinois Agronomy Handbook
iah.aces.uiuc.edu/index.php

University of Missouri Extension
muextension.missouri.edu/explore/agguides/pests/ipm1022.htm

Winter wheat production in North Dakota
www.ag.ndsu.edu/pubs/plantsci/smgrains/eb33w.htm

The Ohio State University Extension
ohioline.osu.edu/iwy/index.html

Purdue University Agronomy Extension
www.agry.purdue.edu/ext/smgrain/index.html

University of Saskatchewan, Saskatoon, Canada
www.usask.ca/agriculture/plantsci/winter_cereals/index.php

University of Wisconsin
soybean.uwex.edu

NITROGEN RATES FOR WINTER WHEAT FOLLOWING SOYBEANS

Tim Wood[1], John Gaska[2], Todd Andraski[3], Kevin Shelley[4], Larry Bundy[5], and Joe Lauer[6]

Introduction

Winter wheat has a strong tradition in Wisconsin, particularly in the south central and eastern counties. It fits well in rotations with canning crops which are popular there. But in recent years, corn and soybean growers who are looking to diversify their rotation also find winter wheat attractive. Wheat typically follows soybeans in the rotation and can be drilled no-till into the soybean residue. This leads to the question: What is the optimum nitrogen (N) application rate for wheat following soybeans?

Methods

Studies were conducted in 2005 and 2006 which compared N rates on winter wheat at two locations in southern Wisconsin: Arlington in Columbia County and Lancaster in Grant County. At the UW-Arlington Ag Research Station, winter wheat was grown in three rotations: following soybeans; following corn harvested as silage; and following corn harvested for grain. Wheat was planted no-till on the same date within each year in all systems. Six rates of N were then applied the following spring: 0, 25, 50, 75, 100 and 125 lb/a.

In a separate study, wheat was planted no-till following soybeans at the UW-Lancaster Ag Research Station. Four N rates were spring-applied: 0, 30, 60 and 90 lb/a. The N source at both locations was ammonium nitrate and it was applied before April 15 in all years.

Results and Discussion

At Lancaster, there was a significant grain yield increase from 0 to 30 lb N/a in both years, but no further response occurred at higher N rates even at very high yield levels (Table 1). Wheat yields at Arlington did not significantly increase above 50 lb N/a in 2005 or above 25 lb N/a in 2006 (Table 2).

Plateau N rate (PNR), the point where wheat yields begin to level off with increasing N rates, ranged from 30-74 lb N/a following soybeans in these studies (Table 3). The PNR averageed 59 lb N/a over the two years and two locations.

The economic optimum N rate (EONR) averaged 34 lb N/a when wheat was priced at $2.90/bu and N was $0.36/lb (Table 3). These prices were typical during the 2006 harvest season. The EONR increased to 42 lb N/a when prices were updated to $4.70/bu for wheat and $0.30/lb for N.

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Comparing N Recommendation Methods

The standard N recommendation for wheat in Wisconsin has recently been revised to 70 lb N/a (Laboski et al., 2006). The book value N credit (BVNC) for soybeans is 40 lb N/a, resulting in a recommended N application of 30 lb/a. This amount matches very closely with the observed EONR using $2.90/bu wheat (Table 5). When the wheat price was $4.70, however, two of the four tests showed responses to N rates above the BVNC.

The preplant soil nitrate test (PPNT) did not identify an N credit at Lancaster in either year (Table 5). PPNT results must exceed 50 lb nitrate-N/a before a credit is applied. For example, if the PPNT totaled 60 lb/a, the N credit would be 10 lb/a. At Arlington the soil nitrate results were not statistically different following soybeans and corn (Table 4). The test did identify a large N carryover (108 lb/a) following corn for grain in 2006. The N recommendation there was close to the EONR (Table 5).

This example compares to previous studies in Wisconsin (Bundy and Andraski, 2004) that showed the PPNT is a useful predictor of N needs when wheat follows a nonlegume crop. It is less accurate and less useful following soybeans.

Conclusions

- When winter wheat follows soybeans, a nitrogen credit should be taken.
- The book value N credit of 40 lb/a results in an N application (30 lb/a) that compares well with the EONR. When wheat prices are higher ($4.70/bu), growers can justify higher N rates, up to ~50 lb/a.
- The PPNT is less reliable in predicting the optimum N rate when wheat follows soybeans than when it follows corn or another nonlegume crop.

Questions for Future Research

- When is the optimum time to apply N in the spring in Wisconsin? Is there an advantage for a later application?
- Do yields respond to split N applications, including a fall treatment?
- Is the N response following soybeans consistent across widely different soil types, such as the red- clay soils of eastern Wisconsin?

References

Bundy, L.G., and T.W. Andraski. 2004. Diagnostic Tests for Site-Specific Nitrogen Recommendations for Winter Wheat. Agron. J. 96:608-614.

Laboski, C.A.M., J.B. Peters, and L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. UWEX Publ. A2809. Univ. of Wisconsin-Extension, Madison, WI.

Table 1. Effect of N rate on no-till winter wheat grain yield where the previous crop was soybean at Lancaster, 2005 and 2006.

	Year	
N rate	2005	2006
lb/a	------------- grain yield, bu/a	------------
0	65 b †	87 b
30	78 a	105 a
60	82 a	105 a
90	83 a	106 a
Mean	77	101
p	<0.01	<0.01
CV, %	8	7

† Values for each location and year followed by the same letter are not significantly different at the 0.05 probability level.

Table 2. Effect of previous crop/management and wheat N rate on no-till winter wheat grain yield at Arlington, 2005 and 2006.

Year	N rate	Previous crop/management			
		Soybean	Corn silage	Corn grain	Mean
	lb/a	yield, bu/a			
2005	0	65	48	40	51 c † ‡
	25	72	56	52	60 b
	50	74	66	52	64 ab
	75	71	67	57	65 a
	100	77	67	53	66 a
	125	73	68	53	65 a
	Mean †	72 a	62 b	51 c	
2006	0	70	61	65	65 c §
	25	74	74	64	70 ab
	50	76	73	63	71 ab
	75	77	72	74	74 a
	100	77	74	68	73 a
	125	71	65	62	66 bc
	Mean §	74 a	70 ab	66 b	

† 2005: Previous crop $p < 0.01$; N rate $p < 0.01$; Previous crop x N rate $p = 0.07$ (NS); CV, 9%.
‡ Mean values for each year followed by the same letter are not significantly different at the 0.05 probability level.
§ 2006: Previous crop $p < 0.01$; N rate $p < 0.01$; Previous crop x N rate $p = 0.30$ (NS); CV, 10%

Table 3. Plateau (PNR) and economic optimum N rate (EONR) for no-till winter wheat grain yield following soybean at Lancaster and following soybean, corn harvested as silage, and corn harvested as grain at Arlington determined using regression analysis, 2005 and 2006.

Location	Previous crop / management	Year	Equation (method †)	R^2	PNR N rate	PNR Yield	EONR ‡ N rate	EONR ‡ Yield
					lb/a	bu/a	lb/a	bu/a
Lancaster	Soybean	2005	$y = 65.1 + 0.602x - 0.00517x^2$ (QRP)	0.99	63	83	46 52	82 82
		2006	$y = 87.2 + 0.614x$ if $x \leq 30$ (LRP)	0.99	30	105	30 30	105 105
Arlington	Soybean	2005	$y = 64.6 + 0.455x - 0.00577x^2$ (QRP)	0.80	74	74	29 34	73 73
		2006	$y = 69.3 + 0.225x - 0.00162x^2$ (Q)	0.88	69	77	31 50	75 77
	Corn silage	2005	$y = 47.6 + 0.357x$ if $x \leq 56$ (LRP)	0.99	56	68	56 56	68 68
		2006	$y = 62.5 + 0.372x - 0.00277x^2$ (QRP)	0.81	67	75	45 56	74 75
	Corn grain	2005	$y = 40.0 + 0.657x - 0.00779x^2$ (QRP)	0.93	63	55	34 38	53 54
		2006	$y = 66 + 0x$ (NS)	-	0	66	0 0	66 66

† QRP, quadratic-response plateau; LRP, linear-response plateau; Q, quadratic; NS, not significant.
‡ Economic optimum N rate determined at $0.36/lb N fertilizer and $2.90/bu wheat grain within the **left** side of the N rate and yield columns and $0.30/lb N fertilizer and $4.70/bu wheat grain within the **right** side of these columns.

Table 4. Soil NO_3-N content (0-2 ft) in the control (no N) in fall (preplant) and/or spring (GS25) where the previous crop was soybean at Lancaster and soybean, corn harvested as silage, and corn harvested as grain at Arlington, 2005 and 2006.

Location	Year	Previous crop / management	Time of sampling: Fall preplant	Time of sampling: Spring GS25
			----------- soil NO_3-N, lb/a -----------	
Lancaster	2005	Soybean	34	33
	2006	Soybean	37	52
Arlington	2005	Soybean	-	44
		Corn silage	-	37
		Corn grain	-	37
		p	-	0.24 (NS) †
	2006	Soybean	61	-
		Corn silage	78	-
		Corn grain	92	-
		p	0.28 (NS) †	-

† The effect of previous crop / management at Arlington was not significant (NS).

Table 5. Preplant soil NO_3-N test (PPNT) contents and N recommendations for winter wheat based on the standard N rate (70 lb N/acre), the standard N rate adjusted for the PPNT, and the standard N rate adjusted using a book value N credit (BVNC) compared with the observed economic optimum N rate (EONR) for several previous crop / management systems at Lancaster and Arlington, 2005 and 2006.

Location	Year	Previous crop / management	PPNT (0-3 ft) †	N recommendation method: Standard	PPNT ‡	BVNC §	Observed EONR*	
			lb NO_3-N/a	------------------ lb N/a	-------------------------			
							Low	High
Lancaster	2005	Soybean	43	70	70	30	46	52
	2006	Soybean	46	70	70	30	30	30
Arlington	2005	Soybean	-	70	-	30	29	34
		Corn silage	-	70	-	-	56	56
		Corn grain	-	70	-	-	34	38
	2006	Soybean	73	70	47	30	31	50
		Corn silage	82	70	38	-	45	56
		Corn grain	108	70	12	-	0	0

† At Lancaster, soil NO_3-N content at the 2-3 ft depth increment was predicted from the 1-2 ft depth increment based on the equation $y = 5.8 + 0.51x$ as determined from 21 winter wheat trials in Wisconsin conducted from 1996 to 1999 (Bundy and Andraski, 2004) where: x, soil NO_3-N (lb/a) at 1-2 ft depth; y, predicted soil NO_3-N (lb/a) at 2-3 ft depth.
‡ PPNT N recommendation = 70 – (PPNT – 50).
§ Book value N credit recommendation = 70 – 40.
* EONR determined for "Low"-- $0.36/lb N and $2.90/bu wheat and "High"-- $0.30/lb N and $4.70/bu wheat.

CAN WE MANAGE WHEAT AND STILL MAKIE A PROFIT?

Wayne L. Pedersen [1]

Introduction

For many years, wheat acreage has continued to decline. When I first came to Illinois in 1980, growers planted nearly 2,000,000 acres and in 2006 they planted approximately 700,000 acres. Poor yields, diseases (especially scab), and poor prices have contributed to reductions in acres. In addition, both corn and soybeans have been more profitable. However, growers in the southern Corn Belt, especially Kentucky, have seen significant increases in wheat yields, often exceeding 100 bu/a. Combined with higher prices and good yields in 2006, more acres were planted to wheat this fall in Illinois. To achieve high yields, growers have focused on improved varieties, uniform stands, fungicide and insecticide seed treatments, proper fertilizer application rates and timing, weed control, and foliar fungicides and insecticides. Our research has focused on fungicide/insecticide seed treatments and foliar fungicides.

One of the major diseases that growers face in Illinois is Barley Yellow Dwarf Virus. It is characterized by a reddish-purple leaves, short plants, and reduced yields. This virus is vectored by aphids and yield losses are most severe if infection occurs in the fall. There is little resistance available to BYDV, so the easiest way to control this disease is with seed applied insecticides that control the aphids in the fall. In addition, the applications of broad spectrum seed-applied fungicides help reduce damage by *Pythium, Rhizoctonia, Fusarium* and *Helminthosporium* root rots. The fungicide seed treatments are very important when growers plant wheat into corn debris, either no-till or minimum tillage. Many of the pathogens that infect corn plants also infect wheat plants and can reduce stand or vigor.

The major disease that limits wheat production in the U.S. is Fusarium head blight or scab. The fungus survives on wheat and corn debris and infects at flowering. Once infected, if the weather conditions are favorable for the fungus, a toxin (DON) is formed, making the grain unfit for human consumption and in severe cases may be unfit for animal consumption. There are several sources of resistance and many varieties have partial resistance, but no varieties have complete resistance. As part of a national fungicide evaluation program, we have found a couple of fungicide effect in reducing both scab and DON levels, but timing is critical. The optimal timing is when anthers are visible and for the next 3 to 5 days. After 5 days, the effectiveness of the fungicides is reduced. This makes controlling scab fairly difficult, but not impossible. The major factor is the weather, but we obviously cannot control that. In 2006, we had fairly dry weather and scab was not an issue for wheat growers. So, by monitoring the weather and using partially resistant varieties and effective fungicides when needed, wheat production can still a very economical alternative to corn and soybeans. In addition, wheat is not a host for soybean cyst nematode, so it is an excellent rotation crop for soybeans.

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Table 1. A summary of fungicide evaluations for the control of Fusarium head blight on wheat in 2002.

Treatment	Rate	Scab incidence	DON	Scab severity	Septoria leaf blight	Yield
		%	ppm	%	%	bu/a
Control		26.3	5.6	16.2	17.5	75.4
Folicur 36F + Induce	4.0 fl oz + 0.125%	1.9	0.6	4.7	11.2	73.3
AMS 21619A + Induce	5.7 fl oz + 0.125%	9.5	2.0	7.4	11.3	77.4
AMS 21619A + Folicur + Induce	5.7 fl oz + 4.0 fl oz + 01.25%	2.3	0.6	4.7	8.8	76.4
Quadris	9.2 fl oz	23.6	4.6	10.2	6.3	73.7
TrigoCor 1448	As directed	12.6	3.3	9.9	13.8	73.1
TrigoCor 1448 + Folicur + Induce	As directed + 4.0 fl oz + 0.125%	2.3	1.2	3.3	11.3	72.3
	LSD (5%)	3.0	1.4	3.7	3.8	NS †

† NS = not significant.

BIOETHANOL PRODUCTION FROM LIGNOCELLULOSE: OPPORTUNITIES AND CHALLENGES

Xuejun Pan [1/]

ABSTRACT

Currently, ethanol counts for about 3% of annual fuel consumption of 140 billion gallons in the United States. Most of the ethanol is made from the starch contained in corn kernel. It is believed that the corn available in US can only produce enough ethanol to replace up to 12% of the nation's fuel supply. Beyond that, another source for the ethanol needs to be found. A promising and sustainable alternative is lignocellulosic biomass. It is the most abundant renewable resource on the earth. The available biomass for cellulose ethanol production includes agricultural crop residues (corn stove, cereal straws, and bargasse), forest residues (forest thinnings, small size and low quality trees), and wastes from industrial processes (sawdust and paper sludge) as well as special energy plants (switchgrass and fast growing trees). However, different from starch in corn kernel, the cellulose in the plants is blocked by other plant components such as lignin and hemicellulose in a matrix, thus not readily available (accessible) to enzymes. How to expose the cellulose to enzymes is one of primary technical and economical challenges in cellulose ethanol production. Other challenges include the development of more efficient enzymes and high-value co-products from lignin and hemicellulose to offset the expensive processing cost. This presentation will briefly review the cellulose ethanol production. The topics covered include:

- Status of bioethanol production
- Difference between corn ethanol and lignocellulose ethanol
- Available processes for lignocellulose ethanol production
- Barriers to lignocellulose ethanol
- Commercialization of lignocellulose ethanol
- Development of biorefineries

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SOURCES AND USES OF BIODIESEL FUELS

Ronald T. Schuler [1/]

Introduction

Interest in renewable energy has heightened due to the uncertainties of the supplies and prices of the fossil/petroleum fuels. Using vegetable and animal oils as a source of diesel fuel provides an alternative solution. The production of biodiesel in the US is becoming increasingly more available. The biodiesel fuels have properties different from petroleum diesel fuel which are both positive and negative with respect to engine performance.

Since most modern diesel engines were designed for the petroleum fuel, some problems would be expected when using biodiesel fuel due to small differences in properties. But these problems can easily be overcome with minor adjustments in engine operation and maintenance and handling of the fuel.

Background

When Rudolph Diesel designed the compression (diesel) engine in 1897, he used peanut oil as the fuel. As the petroleum fuel market evolved with the production of various fuels e.g. gasoline, heating oil and kerosene, the crude oil was refined to produce fuels with traits meeting very specific needs of their final use. Since the time of Diesel's development, the compression ignition engine and diesel fuel properties together have evolved to improve the performance of the engine and to meet environmental air quality requirements.

As environmental air quality requirements become more restrictive, the challenges of designing new engines and modifying fuel properties become greater. The fuel delivery systems on diesel engine were designed and manufactured with greater precision requiring improved lubricating properties of the diesel fuel. As a result the fuel is metered more accurately to the engine cylinders producing more efficient engines and fewer contaminants in the engine exhaust.

To meet environmental air quality requirements, the composition of the fuels was also modified. Sulfur is one of the principal components of concern. The sulfur is very important in determining the lubricity, lubricating ability, of the fuel which became more important with the more precisely manufactured fuel systems.

All these modifications were made without consideration for the biodiesel properties. As these fuels gained more interest, their properties must be compared to the present day petroleum fuels. For some properties the biodiesel fuel has an advantage. For other properties the biodiesel fuel has disadvantages but they can be addressed by using proper fuel additives and properly maintaining and servicing the engine.

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Biodiesel Production and Ssources

Biodiesel can be produced from a variety of sources including algae, discarded cooking oil and agricultural crops. In 2002, the primary world source of biodiesel was canola/rapeseed at 84%. Sunflowers were second at 13%; soybeans and palm oil each contributed 1% to the world market. The eastern European countries appear to be the leaders in biodiesel production with approximately 550 million gallons in 2002 (Biodiesel, 2006). The production of biodiesel in the US primarily from soybeans has been increasing dramatically each year since 2001, Figure 1. The production from 1999 to the present has nearly doubled each year.

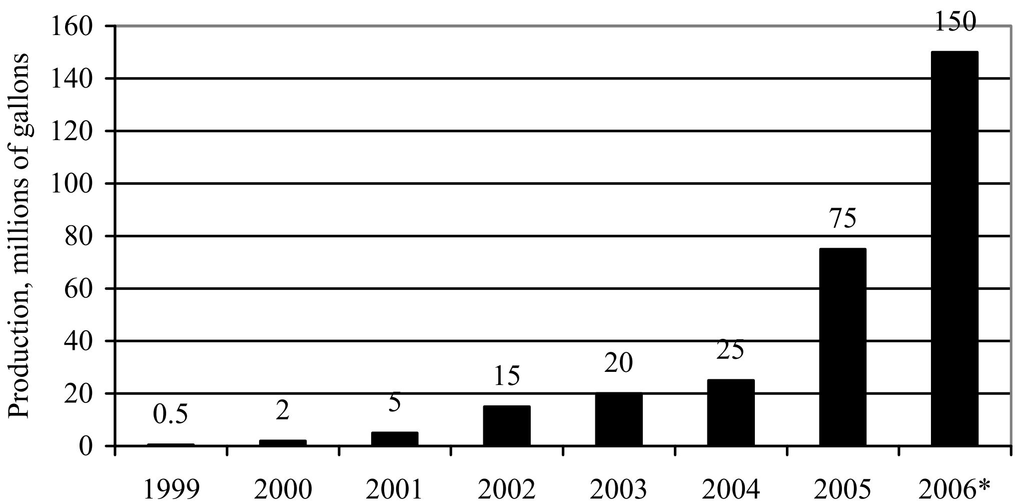

Figure 1. Production of Biodiesel Fuel in the US (*2006 estimate).

The primary Midwestern US and Central Canada crops considered for production of biodiesel are canola, sunflowers, safflowers and soybeans. This discussion will include corn because the oil is a potential by-product of the ethanol process or other processes.

Oil production per acre will be dependent on the seed yield and the oil content of the seed and will vary from year-to-year. Using average yield data, canola produces the greatest quantity of oil per acre (127 gallons) followed by sunflowers, safflowers, soybeans and corn in that order, see table. Corn has the lowest production per acre (18 gallons), Figure 2 (Kurki et al. , 2006).

Differences Between Biodiesel and Petroleum Diesel

The biodiesel produced from crop oil has characteristics which provide several advantages over the petroleum diesel fuels. Examples of these characteristics are lubricity, cetane rating and environmental pollutants. Although the biodiesel fuels has some disadvantages with regard to petroleum fuels, many can be overcome with the use of additives or the use proper fuels storage and handling and proper maintenance and service of the diesel engines. Examples are cloud point temperature, water contamination and solvent properties. In other cases differences are small, e.g. energy content, especially when blends of biodiesel are used.

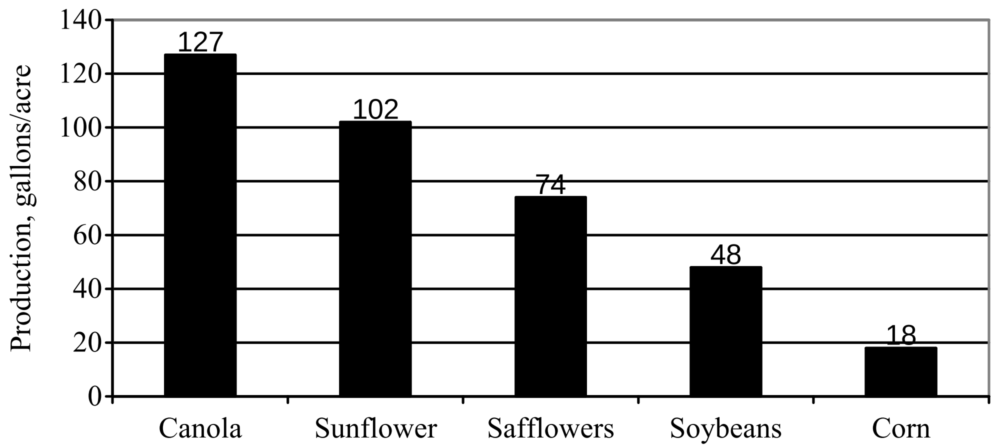

Figure 2. Production of oil in gallons per acre.

Lubricity is the ability of the fuel to lubricate which is especially important in the fuel pump and injectors where clearances between parts are very small and pressures may be rather high. Sulfur in the petroleum diesel fuels provides improved lubricity, which is indicated by the scar diameter produced during a ASTM D6079 standard test called Ball on Cylinder Lubricity Evaluator (ASTM, 2006). A larger scar diameter indicates lower lubricity. The sulfur in the exhaust contributes to environmental problems.

For petroleum diesel fuels number 1 and 2 the lubricity diameters are 670 and 540 microns respectively, Figure 3. Adding 1 to 2% by volume of biodiesel to petroleum diesel fuel significantly improves the lubricity of diesel fuel, Figure 3 (Lubricity, 2006). Increasing the biodiesel blend beyond 2% has very little impact on the diesel fuel lubricity improvement, see Figure 3. Also the biodiesel has a greater impact on diesel fuel number 1. One of the agriculture equipment manufactures recommends a maximum of 450 micron in the new tractors. The fuel produced from crops reduces the need for sulfur to obtain the desired lubricity characteristics.

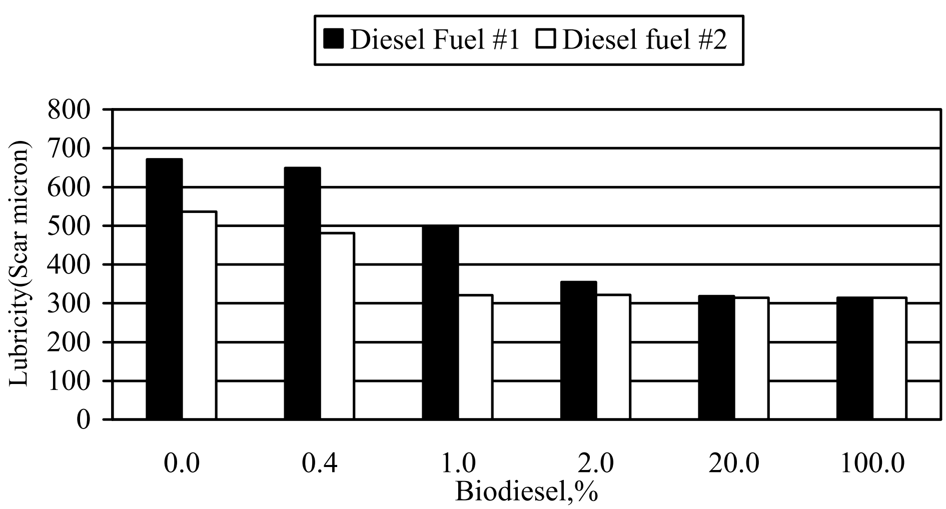

Figure 3. Lubricity for diesel fuel and blends of biodiesel.

The biodiesel blends have reduced emissions of some pollutants but other may increase. Sulfur, aromatics and hydrocarbons emissions will be less but the nitrous oxides will increase slightly. The most important pollutant would be the sulfur because the biodiesel reduces the need for sulfur to insure the lubricity needs of a diesel engine.

During cold weather fuel clouding or wax separation may occur, especially with higher blends of biodiesel which is referred as the cloud point. This may lead to fuel filter clogging and hard starting. This should not be a problem with blends of five percent biodiesel but is a concern at higher levels. One tractor manufacturer recommends the cloud point should be 10^{o}F below the coldest temperature. The pour point is the temperature where the fuel is no longer pumpable, resulting no fuel being delivered to the engine, leaving it inoperable. Sunflower oil exhibits the highest cloud point, 45^{o}F, see Figure 4 (Kurki et al., 2006).

If 100% biodiesel is going to be used, at least two solutions are available to address the cloud and pour point problems. Heating the fuel to a temperature about 10^{o} above the cloud point will reduce the problem but would require modifications to the engine and its fuel tank. Additives are on the market for lowering the cloud and pour points of diesel fuel. The additives may be referred to as pour point depressants or antigels. Based on market information on fuel additives, there appears to be some additives developed specifically for the biodiesel fuels.

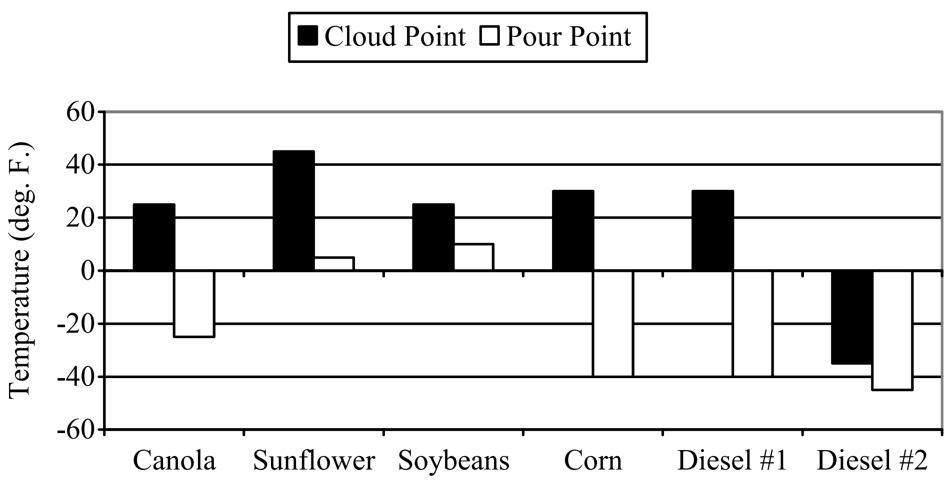

Figure 3. Pour and Cloud points for several diesel fuels.

Cetane rating describes the ignition characteristics of diesel fuel. Using a diesel fuel with a cetane rating lower than the manufacturers' recommendation can be detected by the diesel knock produced. The comparable gasoline property is octane rating which is referred to anti-knock rating. Fuels with higher ratings will cause an engine to operate more efficiently and will tend to start more easily. Most petroleum diesel fuels on the market range from 40 to 55. The biodiesel fuels have higher ratings than the standard petroleum diesel fuels (Figure 4), noting the differences are small, with canola being slightly higher (Kurki et al., 2006).

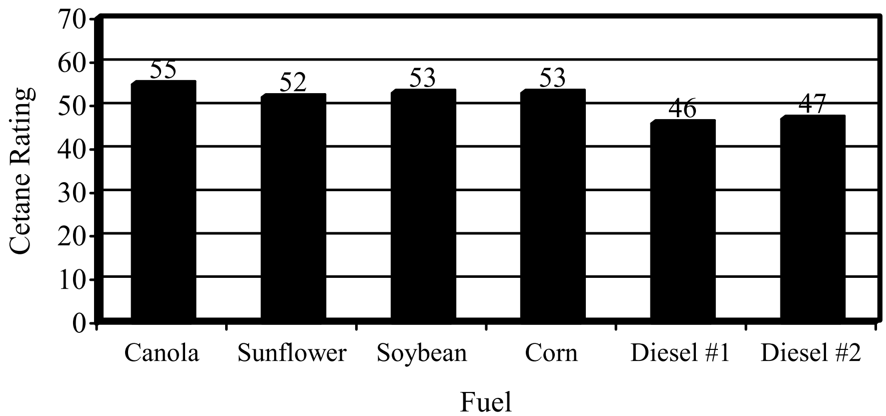

Figure 4. Cetane rating of diesel fuels from various sources.

For older engines, a minimum cetane rating of 40 is frequently recommended. For modern tractors, one manufacturer recommends a minimum cetane rating of 45 but 50 is preferred. The ratings for biodiesel are above the preferred rating which should not create a problem. Operators of diesel engine powered equipment should check the operator's manual for the recommended cetane number. For some older equipment the recommended cetane may not be listed in the operator's manual.

Other issues regarding biodiesel fuels include moisture absorption and some seal and material compatibility. All these issues become more important when using higher blends of biodiesel. Nonetheless, at the 5% level several normal recommended practices should be used. With moisture absorption, there is an increased risk of microorganism growth in the fuel tank which may lead to an increased clogging of the fuel filters. Any steps to reduce the potential of water entering the fuel system should be followed. Examples include insuring fuel caps are properly installed, more frequently draining the water from the water trap on an engine, keeping tanks filled, including storage tanks, and adding a water trap on the fuel storage tank to separate the water from the fuel as it is drawn from the storage tank.

When changing from diesel to biodiesel, more contaminants will be present in the fuel initially because the biodiesel acts as a solvent. In the fuel tanks, the biodiesel will breakdown some of the contaminants adhering to the inside wall of the tank. Therefore fuel filters may need to be changed more frequently immediately after changing to the biodiesel. The filters can be changed at the normal recommended interval after several filter changes. One manufacturer recommends changing at one half the normal intervals for the first several filter changes.

The energy available in each pound of biodiesel fuel is eight to ten percent less than petroleum diesel fuel. For canola and soybean derived biodiesel, lower heating value is about 17,900 and 17,400 BTUs per pound respectively, (Auld et al., 1982). For petroleum diesel fuel it is 19,300 BTUs per pound. The density of biodiesel is about four to five percent greater than the petroleum diesel fuel. Therefore the difference is less when considering the energy in a gallon of fuel but the biodiesel fuel is still slightly less. Under normal engine loads and at 20% or less for biodiesel blend, the operator will not likely perceive a difference in engine performance when switching to biodiesel.

Selecting a Biodiesel Source

Diesel engine manufactures specify the fuel for use in their engines must meet standards set by American Society for Testing Materials (ASTM). The current standard for diesel fuel (ASTM D975-06b, 'Standard Specifications for Diesel Fuel Oils') is specified in new engines (ASTM, 2006). This standard is used by engines manufactures to address warranty issues. If the biodiesel blend meets this standard, the fuel will not cause a warranty to be voided.

ASTM has a standard that is specifically for biodiesel fuel blend stock. 'Standard Specifications for Biodiesel Fuel Blend Stock' (ASTM 6751-06a) is designed for the 100 percent biodiesel that is blended with the petroleum diesel fuel (ASTM, 2006). The standard consists of numerous ASTM methods for determining characteristics of the fuel. Examples of characteristics specified by the methods are cetane rating, cloud point, sulfur, water, sediment and glycerin.

To ensure fuel quality, the National Biodiesel Board established a Quality Assurance Program Requirements for the Biodiesel Industry called BQ-9000. This voluntary program provides an opportunity for biodiesel producers to be gain accreditation by meeting requirements for providing quality fuel and the fuel meets the ASTM 6751 specifications. In addition the board has a program voluntary program for certifying marketers who meet the requirements regarding the handling and storage of biodiesel.

Summary

Biodiesel oils from the various crops are very similar with respect to efficiency, cetane rating and lubricity. Some of the biodiesel fuels have higher cloud and pour points, making them more undesirable for Wisconsin operation unless additives are used or engines modified. The greatest difference among the various sources of biodiesel fuel is the production per acre, where canola is the highest. The importance of these differences will be impacted by the uses of by-products from the manufacturing of the biodiesel fuel and the availability of the crop. Biodiesel blend of 20 percent or less can be used successfully in Wisconsin weather conditions using proper storage and appropriate engine maintenance practices.

Information Sources

ASTM. 2006. American Society for Testing Materials. West Conshohocken, PA

Auld, D.L., B.L. Bettis and C.L. Peterson. 1982. Production and fuel characteristics of vegetable oilseed crops in the Pacific Northwest: Vegetable oil fuels. p. 92-100. *In* Proc. Internatl. Conf. on Plant and Vegetable Oils. Am. Soc. Agric. Engr.

Biodiesel. 2006. Accessed at www.cyberlipid.org/glycer/biodiesel.htm

Kurki, A., A. Hill, and M. Morris. 2006. Biodiesel: The sustainability dimensions. Accessed September 29, 2006 at attra.cat.org

Life Cycle Inventory of Biodiesel and Petroleum Diesel. NREL/SR-580-24089. Accessed October 3, 2006 at www.worldenergy.net/news/doc.asp

National Biodiesel Board. 2006. BQ-9000 Quality Assurance Program Requirement for the Biodiesel Industry. 18 pp.

Schuler, R.T. 2006. **Biodiesel Fuels in Agricultural Equipment**, Wis. Crop Mgr., Vol. 13(21), Aug 13, 2006.

U.S. AGRICULTURE'S ROLE IN THE INTERNATIONAL BIOFUELS MARKET

Chad Hart[1]

Abstract

The 2002 Farm Bill was the first farm bill to include an energy title, looking at the potential for U.S. agriculture to partially fulfill domestic energy needs. Congress and the Bush Administration passed the 2005 Energy Policy Act, establishing standards for biorenewable fuel usage in the U.S. President Bush, in his 2006 State of the Union address, made ethanol and U.S. energy security priorities for the federal government. Thus, the federal government has concentrated efforts to expand biorenewable fuel production and consumption over the past few years. And we have seen a dramatic increase in the production and usage of biorenewable fuels over the past 5 years.

This switch to biorenewable fuels is not limited to the U.S. Brazil has made a strong commitment of biorenewable energy over the last 30 years. In fact, 40% of Brazil's fuel needs are filled by domestic ethanol from sugarcane. The European Union (EU) has set a goal of replacing 20% of their fuel needs with alternate fuels, including biorenewable fuels, by 2020 and has put in place directives to increase biofuel usage to 5.75% of EU transportation fuel needs by 2010. China and India's growing economies are driving those countries to consume ever increasing amounts of energy. Both countries have moved to explore renewable sources of energy.

World trade in biorenewable fuels is starting to pick up with the increased demand for fuel worldwide. In terms of production, the U.S. and Brazil lead the way in biorenewable fuels, each producing roughly 5 billion gallons of ethanol in 2006. China produced over one billion gallons of ethanol. But in terms of trade, Brazil is the largest exporter of biorenewable fuels. In 2006, the Brazilians exported over 1 billion gallons of ethanol, with a sizable portion of that going to the U.S. The U.S. is the largest importer of biorenewable fuels, even with the dramatic expansion of the domestic ethanol industry over the past several years.

The outlook for biofuels is that the U.S. will overtake Brazil next year as the world largest producer of ethanol with production levels exceeding 10 billion gallons within a few years. Despite this growth, the U.S. is expected to remain as the largest importer of ethanol. In fact, China, India, the EU, and the U.S. are all expected to be major importers of biorenewable fuels for the foreseeable future with Brazil serving as the lone major exporting country.

In the short term, U.S. agriculture, especially corn, will provide a sizable amount of feedstock for world biofuel production, but this will not translate in export opportunities for the U.S. as domestic consumption of biofuels is projected to outpace production growth. Longer term, if efforts to make cellulosic ethanol or other biofuels come to fruition, biofuel production will gather feedstock from various other agricultural and forestry sources. This would make the biofuel industry less corn-specific, but still dependent on the agricultural sector to provide the vast quantities of biomass needed to meet the renewable energy goals laid out by the President and the Congress.

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POLYMER-COATED UREA (ESN) FOR CORN

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Introduction

Improved nitrogen (N) management in corn production is needed to optimize economic returns to farmers and minimize environmental concerns associated with agricultural N use. Nitrogen losses through nitrate leaching can reduce the efficiency of N fertilizers and contribute to elevated nitrate concentrations in groundwater. Concerns about nitrate leaching are particularly relevant in areas with course-textured soils receiving N fertilizer inputs for intensive, irrigated crop production, such as the Central Sands Region of Wisconsin. Several strategies have been used to control N leaching losses on sandy soils including use of delayed (sidedress) or multiple split applications of N and the use of nitrification inhibitors with ammonium forms of N fertilizers to delay the conversion of ammonium N to nitrate which is susceptible to loss by leaching. Slow-release N fertilizers have been available for many years, but their higher cost has usually limited their use to high value specialty crops. Recently, a polymer-coated urea product (ESN) has become available at a lower cost than traditional slow-release N fertilizers. This product may have potential for controlling N leaching losses from applied N and could allow greater flexibility in the timing of N fertilizer applications relative to conventional fertilizer materials. The polymer coating on the ESN material allows water to diffuse into the capsule, dissolve the urea and allows urea to diffuse back into the soil solution over an extended period of time. Typically, release of urea from the polymer-coated granules is complete in about 6 weeks after application. The release process is also temperature dependent so that the rate of urea release increases as temperature increases. The delayed release of urea from the polymer-coated material could help to avoid N leaching losses during the early part of the growing season and could allow application of the fertilizer material earlier in the growing season without greatly increasing the risk of N loss.

Since little is known about the relative performance of polymer-coated urea compared to the traditional N management methods typically used on sandy irrigated soils, such as split sidedress N timings and addition of nitrification inhibitors to fertilizer N, this study was initiated to provide that information. The objectives of this study were to determine optimum times and rates of several N fertilizer materials (including polymer-coated urea) for corn production on sandy irrigated soils. Use of a nitrification inhibitor with selected N sources and times of application was also evaluated.

Materials and Methods

Research to accomplish project objectives was conducted during 2003 to 2006 on sprinkler irrigated Plainfield loamy sand soils (sandy, mixed, mesic Typic Udipsamments) at the University of Wisconsin Agricultural Research Station at Hancock, WI (44°,7'N, 89°,32'W). The experiments were located where the preceding crop was a non-legume (potato, field corn, or sweet corn) to avoid legume N contributions to the test crop.

Treatments were arranged in a split plot design with four replications. Nitrogen source and timing were the main plot treatments and N rate was the sub-plot treatment. Nitrogen fertilizer sources, application times, and rates used in the 2004-2006 experiments are summarized in Table 1. Treatments in 2003 used 28% urea-ammonium nitrate (UAN) solution in place of urea, and

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ESN was not applied using the sidedress at 4 wk and the split-sidedress (4 & 6 wk) application times.

Table 1. Nitrogen treatments evaluated in the 2004 to 2006 N management experiments at Hancock, WI.

I. Control (0 lb N/acre) + 40 lb S/acre †

II. Polymer-Coated Urea (ESN)
   A. Preplant: 100, 150, 200, and 250 lb N/acre + 40 lb S/acre †
   B. Split (Preplant & 4 wk): 100, 150, 200, and 250 lb N/acre + 40 lb S/acre †
   C. Sidedress at 4 wk: 100, 150, 200, and 250 lb N/acre + 40 lb S/acre †
   D. Split-sidedress (4 & 6 wk): 150 and 200 lb N/acre + 40 lb S/acre †

III. Ammonium Sulfate (AS)
   A. Preplant: 150 and 200 lb N/acre
   B. Preplant + nitrification inhibitor (DCD): 150 and 200 lb N/acre
   C. Sidedress (4 wk): 150 and 200 lb N/acre
   D. Split-sidedress (4 & 6 wk): 100, 150, 200, and 250 lb N/acre

IV. Urea
   A. Preplant: 150 and 200 lb N/acre + 40 lb S/acre †
   B. Sidedress (4 wk): 150 and 200 lb N/acre without S
   C. Sidedress (4 wk): 150 and 200 lb N/acre + 40 lb S/acre †

† S source = gypsum

Because the ammonium sulfate (AS) contains sulfur, a preplant broadcast application of gypsum ($CaSO_4$) providing 40 lb S/acre was made to treatments where the N source was not AS. The only exception to this was the 4-wk sidedress urea treatment which had a "with" and "without" S treatment to confirm potential response to sulfur. The preplant gypsum and N treatments were applied before planting following moldboard plowing and disking. The entire site was disked again and planted on in late April or early May. Individual plots were 12 ft (4 rows) wide and 35 ft long. An adapted corn hybrid was planted at 32, 200 seeds/acre and starter fertilizer (100 lb/acre of 5-10-30) was applied in a band 2 inches below and 2 inches laterally from the seed at planting. After emergence, plant stands were thinned to a uniform density of 31,500 plants/acre. Conventional herbicides were applied to control weeds.

Preplant N treatments consisted of broadcast applications of polymer-coated urea (ESN), AS, and urea. For the AS preplant plus nitrification inhibitor treatment, dicyandiamide (DCD) was surface broadcast applied on top of the AS at a rate of 10 lb a.i./acre using a backpack sprayer. For the ESN preplant + 4 wk treatment, 50% of the N was applied preplant and 50% about four weeks after planting. For the split sidedress application of AS, 50% of the total N rate was applied four weeks after planting and the remaining 50% about six weeks after planting. The 4- and/or 6-wk sidedress applications were made by placing the fertilizer materials (ESN, AS, and urea) in a band about 4 to 6 inches deep between corn rows and immediately covering the materials with soil. The split sidedress application timing is the standard N application method used by growers in the region, and a full range of N rates were included to obtain a complete N response curve for the ESN preplant, the ESN preplant plus 4-wk sidedress, the ESN 4-wk sidedress, and for the AS split-sidedress (4- and 6-wk) treatments. A full range of rates was included for the ESN treatments, except the split-sidedress, since this material has not been previously evaluated.

Treatment effects on dry matter yield and total plant N uptake were determined by hand-harvesting six corn plants from each plot at physiological maturity using the method of Walters (personal communication). The ears (cob and grain) were removed, dried in a force-draft dryer at 160°F, shelled, and dry weights of the cob and grain were recorded. Plants (excluding ears) were weighed, chopped, sub-sampled, and dried. All tissue samples were ground to pass a 1-mm mesh screen, and analyzed for total N as described by Nelson and Sommers (1973) using automated analysis.

Grain yield and moisture content was determined by machine harvesting the middle two rows of each plot using a plot combine equipped with a Harvestmaster Graingage moisture and weighing system. Data were subjected to an analysis of variance to determine the treatment effects and their interactions on all measured parameters using PROC ANOVA (SAS Institute, 1992). Mean separation analysis (LSD) was done where main effect means were significant and at each level of the interacting factor if main effect interactions were significant at the 0.05 probability level. The economic optimum N rate was determined using regression analysis using treatment means (PROC REG) and adjusted for the price of N fertilizer and corn grain appropriate for the years when the experiments were conducted.

Precipitation and irrigation amounts varied widely among the four growing seasons (Table 2), and these differences likely influenced the performance of the N treatments evaluated. Irrigation amounts in 2003 through 2006 were 14, 10.3, 10, and 13.7 inches, respectively. In general, the 2003 and 2006 growing seasons had substantially below normal precipitation. In both of these years, May rainfall was above normal, but all of the subsequent months were below normal. The 2004 season was characterized by excessive rainfall during May and June with below normal rainfall during the following months. In 2005, rainfall was near normal for the growing season with only July having above normal monthly precipitation.

Table 2. Monthly precipitation amounts during the growing season 2003-2006, Hancock, WI.

Month	2003	2004	2005	2006
	---------- inches ----------			
May	4.62 (1.35) †	6.42 (3.15)	2.86 (-0.41)	5.1 (1.7)
June	3.21 (-0.43)	6.98 (3.34)	3.18 (-0.46)	1.4 (-2.4)
July	2.13 (-1.47)	2.82 (-0.78)	5.59 (1.99)	2.6 (-1.0)
August	0.58 (-3.34)	2.92 (-1.00)	3.34 (-0.58)	2.8 (-1.1)
September	2.75 (-1.44)	0.50 (-3.69)	3.91 (-0.28)	3.3 (-0.89)
Total	13.29 (-5.33)	19.64 (1.02)	18.88 (0.26)	15.2 (-3.69)

† Numbers in parentheses are the departure from the 30-yr average.

Results and Discussion

Average corn grain yields obtained with the 150 and 200 lb N/acre N rates applied using various N sources and times of application are shown in Table 3. The control plot yields (no N applied) indicate that a strong response to added N occurred each year with fertilized yields about two times greater than those in the control treatment. In 2003 and 2006, no significant differences occurred among the N treatments used reflecting the very low nitrate leaching potential in these two years with substantially below normal growing season rainfall.

Table 3. Effect of N source and timing on corn grain yield, Hancock, WI, 2003-2006.

N source	N timing	Year			
		2003	2004	2005	2006
		--------------------- Yield, bu/acre†	--------------------------		
None		107	115	96	95
ESN‡	Preplant (PP)	204 a	167 c	186 ab	182 NS
	PP & 4 wk	205 ab	180 b	189 a	182
	4 wk	--	--	185 ab	176
	4 wk & 6 wk	--	--	183 ab	177
Am. Sulfate	PP	196 ab	132 e	175 b	180
	PP + NI	202 ab	136 e	183 ab	189
	4 wk	--	181 b	180 ab	176
	4 wk & 6 wk	194 abc	196 a	182 ab	182
Urea‡	PP	--	141 de	154 c	181
	4 wk	--	151 d	181 ab	180
without S	4 wk	--	151 d	177 b	175

† Average of yields obtained with 150 and 200 lb N/acre rates.
‡ 40 lb S/acre applied preplant as gypsum.

In 2004, substantial nitrate leaching likely occurred due to the excessive early season rainfall. Daily precipitation records indicate that 6.6 inches of rain occurred during the 4 wk following planting and that an additional 6.4 inches was received during the next two weeks. This means that N treatments applied preplant and at 4 wk after planting were subjected to substantial leaching pressure, but little rainfall occurred after the 6-wk N application timing. In this environment, preplant ESN performed much better than either preplant ammonium sulfate (AS) or urea. The preplant-sidedress ESN treatment had higher yields than with preplant ESN. Using the nitrification inhibitor DCD with preplant AS apparently had no effect on controlling nitrate leaching since yields with this treatment were similar to those with preplant AS alone. Potentially, the DCD leached below the N fertilizer or out of the root zone and was ineffective in controlling nitrification of the AS. The split sidedress (4 wk & 6 wk) application of AS was more effective than the 4 wk sidedress AS treatment and the split PP & 4 wk ESN treatment. This is probably due to little leaching potential after the 6 wk application time. Preplant urea was similar to preplant AS in that both treatments likely experienced substantial leaching losses. Urea applied sidedress at 4 wk was less effective than AS applied at 4 wk or the PP & 4 wk split ESN treatment. In general, the results show that under heavy leaching pressure, preplant ESN was superior to other N sources applied preplant. However, a 4 wk & 6 wk split sidedress treatment with AS gave higher yields and was apparently more effective in controlling leaching losses than the other treatments.

In 2005, a year with near normal growing season rainfall but with above normal rainfall in July, substantial yield differences occurred among N sources at the preplant application time. Preplant ESN was more effective that either preplant AS or urea, and preplant urea was less effective than preplant AS. However when all or part of the N was applied sidedress, there were no significant corn yield differences among the N sources. It should be noted that preplant ESN was as effective as sidedress or split sidedress application of either AS or urea. Adding the nitrification inhibitor DCD to AS gave yields equal to those with preplant ESN or with sidedress or split sidedress AS or urea treatments.

Economic optimum N rates (EONR) and corn yields at the EONR are shown in Table 4 for ESN and AS treatments. In general, lower EONR values suggest that a treatment is more efficiently used by the corn crop. For the ESN treatments, EONR usually decreased between preplant and split or sidedress treatments, indicating greater efficiency with the split or sidedress treatments. In the high leaching year of 2004, EONR was lower for the split sidedress AS treatment than for the two ESN treatments, again suggesting greater efficiency with the AS treatment.

Table 4. Economic optimum N rates (EONR) and corn yields at the EONR for several polymer-coated urea and ammonium sulfate treatments.

	Polymer-coated urea (ESN)			Ammon. sulfate
Year	Preplant	Preplant & 4 wk	4 wk	4 wk & 6 wk
	------------------------------- EONR †, lb N/acre ------------------------------			
2003	200 (218)	181 (207)	--	189 (196)
2004	227 (173)	215 (190)	--	193 (202)
2005	165 (189)	158 (193)	152 (187)	167 (184)
2006	123 (182)	115 (185)	102 (174)	90 (181)

† EONR based on relationship between N rate and corn yield obtained with five N rates (0-250 lb N/acre. Values in ( ) are yields (bu/acre) obtained at the EONR.

In an attempt to summarize the effectiveness of the various N treatments evaluated during the 4-year study, average yields and apparent fertilizer N recovery for the N source and timing treatments are shown in Table 5. The N recovery values shown are based on total above ground N uptake by corn in the treatment specified and provide an indication of the extent of N loss by leaching since N that is not recovered by the crop during the growing season is most likely lost. In comparing preplant N treatments, ESN has a yield advantage and slightly higher N recovery compared to AS or AS with a nitrification inhibitor. Preplant urea is much less effective than the other preplant treatments and is apparently subject to much greater N loss with only 19% of the applied N recovered by the crop. The split and sidedress treatments applied as ESN or AS generally had higher yields and recoveries than the same materials applied preplant, but urea had lower yields and recoveries than the ESN or AS treatments. In fact, preplant ESN had higher yields and recoveries than sidedress urea. The 4 wk & 6 wk split sidedress AS treatment had similar yields as the ESN preplant & 4 wk application, but N recoveries were somewhat better with the AS treatment. Compared to the AS 4 wk sidedress treatment, the ESN preplant & 4 wk application had higher yields but similar N recovery.

Table 5. Average yields and % recovery of fertilizer N with various N sources and times of N application, Hancock, WI, 2003-2005.†

Treatment	Yield, bu/acre	% N recovery
ESN, preplant	185	44
Ammonium sulfate, preplant	171	41
Amm. Sulf. +NI‡, preplant	178	43
Urea, preplant	159	19
ESN, preplant & 4 wk	189	49
Amm. Sulf. , 4 wk	179	50
Amm. Sulf. , 4 wk & 6 wk	189	56
Urea, 4 wk	171	35

† Apparent recovery of fertilizer N calculated by subtracting N uptake in control (no N) from total N uptake in treatment ÷ amount of fertilizer N applied x 100. Average control yield (2003-2005) = 103 bu/acre, Control N uptake = 67 lb N/acre.

‡ NI=Nitrification inhibitor, DCD.

Summary and Conclusions

In years with normal or below normal precipitation, a single preplant application of ESN is as or more effective than sidedress or split applications of AS or urea. Preplant ESN performed better than other preplant N sources (AS and urea) in terms of yield and fertilizer N recovery. Yields and fertilizer N recovery with preplant AS were higher than those with preplant urea. Using a nitrification inhibitor with preplant AS increased yields and fertilizer N recovery some years, but not in a year with excessive early season rainfall. Our 4 years of data show that ESN is much better as a preplant treatment in wet years than conventional fertilizers; however, split applications of AS are superior to preplant ESN in high rainfall years. This means that relying on preplant ESN as a general practice would involve risk of reduced performance in wet years. With and without sulfur comparisons did not show a corn yield response to added S in any of the four years.

References

Nelson, D.W., and L.E. Sommers. 1973. Determination of total nitrogen in plant material. Agron. J. 65:109-112.

SAS Institute, Inc. 1992. SAS/STAT user's guide. Release 6.03/4th ed. SAS Inst., Cary, NC.

CONTROLLED-RELEASE NITROGEN IN TREE NURSERIES[1/]

Ryosuke Fujinuma and Nick J. Balster[2/]

Introduction

Nitrogen management in nursery systems faces two challenges: improving seedling quality and reducing environmental impacts on adjacent ecosystems. Nursery management is generally based on the concept of "bigger seedlings are good seedlings." Guidelines for seedling quality have been developed based on seedling size and other physical features (Thompson and Schultz, 1995; Dey and Parker, 1997; Kormanik et al., 1998; Jacobs et al., 2005). Seedling performance after outplanting suggests that soil management under conditions of luxury consumption will improve chemical seedling-quality (Timmer, 1997). Maintaining large plant-available nitrogen pools in nursery soils requires large amounts of nitrogen fertilizer over a growing season because of the complexity of the soil nitrogen cycle, the sandy soil texture, and intensive irrigation events typical of tree nursery systems. Thus, maintaining luxury-consumption conditions with nitrogen fertilizer could generate excessive soil nitrogen levels in nursery systems, which may lead to nitrate groundwater contamination.

Using organic fertilizers (slow-release fertilizer) or matching seedling demand with timing of fertilizer applications (i.e., exponential fertilization) are potential solutions for conservation nitrogen-fertilizer management. Slow-release fertilizer strategies are popular in public opinion, however the contribution of nitrogen (N) from slow-release fertilizer varies by field condition, climate, and cropping system (Kirchmann and Bergstrom, 2001; Borken et al., 2004; Jaber et al., 2005). Exponential fertilization works by applying small amounts of nitrogen fertilizer when seedlings are small and larger amounts of nitrogen during later growth stages (Imo and Timmer, 1992; Timmer, 1997; Birge et al., 2006). Exponential fertilization increases nutrient use efficiency, resulting in significantly greater (up to 260 %) biomass production in oak and pine seedlings relative to multiple even-rate fertilizer applications (Salifu and Timmer, 2003; Birge et al., 2006). However, as with slow-release fertilizers, exponential fertilization has higher associated costs, as this strategy requires increased gas, labor, and machine maintenance.

Controlled-release fertilizer (CRF) has been recently considered as a third alternative to minimize excessive N leaching from nursery ecosystems (Alva, 1992; Juntunen et al., 2003). Even though the nitrogen release pattern from CRF differs by product due to differences in the coating material, the general release pattern starts with an exponential application and ends with decadal release after the contained nitrogen becomes lower than its solubility (Shaviv, 2001). The effects of CRF application on crop production appear in fruit production, often with higher nutrient use efficiency (Broschat and Moore, 2001; He et al., 2003; Alva et al., 2003; Alva et al., 2006). Theoretically, CRF should be able to reduce the amount of fertilizer input without sacrificing seedling quality. However, few studies on hardwood species have examined nitrogen leaching and seedling production under the different patterns of nitrogen inputs in bare-root nursery conditions.

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In this project, we test the hypothesis that equal amounts of nitrogen supplied by CRF application will produce greater seedling biomass and nitrogen uptake relative to conventional fertilizer because of the closer matching of nitrogen supply and seedling demand.

Materials and Methods

Experiments were established in two Wisconsin state nurseries: Hayward State Nursery (Hayward, WI. N 46°0', W 91°5') and F.G. Wilson State Nursery (Boscobel, WI. N 43°1', W 90°7'). Prior to setting up the experiment, soil at all sites was fumigated with methyl bromide for ten days. The acorns of northern red oak (*Quercus Rubra* L.) were seeded with an average density of 100 acorns m^{-2} on November 2004. Liquid mulch was applied two weeks after seeding to reduce wind erosion and acorn movement during the winter period.

Conventional fertilizer (CONV), ammonium sulfate (21-0-0), and CRF were applied in three replicated rows (1.2 m by 167 m) during the 2005 growing season. CONV was applied eight times from May to August with the rate of 114 kg ha^{-1}, totaling 914 kg ha^{-1} (192 kg N ha^{-1}) during a growing season. CRF was applied twice (450 kg ha^{-1} in November 2004 and 462 kg ha^{-1} in May 2005) totaling 914 kg ha^{-1} (192 kg N ha^{-1}). Soil samples were taken every other week from May to October to evaluate the dynamics of nitrogen in bare-root nursery systems.

Biomass samples (i.e., red oak seedlings) were separated into leaf, stem, and root and air-dried (65°C) for 2 weeks. The samples were weighed (±0.01 g) and ground using Wiley-mill with #60 mesh screen. Total biomass nitrogen in samples was measured by semi-micro Kjeldahl digestion with titration analysis (±0.01%). The rates of net-nitrogen mineralization were measured by resin-bag method (Brye, 1999). Nitrogen leaching was estimated using mass-balance equations.

Results

The amount of released nitrogen from CRF granules was approximately 85% of applied amount of nitrogen at the end of the growing season of 2005, based on the daily mean soil surface temperature and moisture (Fujinuma, unpublished data). Thus, the nitrogen input from fertilizer under CRF management was estimated as 163 kg N ha^{-1} during the 2005 growing season. The coating membrane shells on the soil surface were easily recognized in the beginning of the 2006 growing season (Fujinuma, field observation).

Total biomass of northern red oak seedlings tends to be greater under CONV management than CRF management regardless the site differences although there is a slight interaction of site difference and fertilizer types (Table 1). Total biomass is 40% less under CRF management relative to CONV management at Wilson, but only 5% less in CRF management relative to CONV management at Hayward. The interaction between site difference and fertilizer type shows that the fertilizer type influences the root-shoot ratio differently by site. The root-shoot ratio at Wilson shows 50% higher ratio ($p < 0.10$) in CRF management relative to the ratio in CONV management. However, there is no significant difference between the treatments at Hayward (Table 1).

Total seedling nitrogen uptake in this experiment shows no significant influence from either site difference or fertilizer type (Table 1). However, there is a significant interaction ($p < 0.10$) of site difference and fertilizer type on the allocation of seedling nitrogen, which is expressed as root-shoot ratio of seedling nitrogen (Table 1). This interaction suggests the influence of fertilizer type on the allocation of seedling nitrogen depends on site difference. The seedlings allocate 75% more nitrogen to root under CRF management than under CONV management at Wilson. Alternatively, the oak seedlings allocate 33% less nitrogen to roots under CRF management than under CONV management at Hayward.

Table 1. Biomass and nitrogen uptake of northern red oak seedlings by conventional fertilizer management (CONV) and controlled-release fertilizer management (CRF) in bare-root nurseries Wilson and Hayward. The values in parentheses show standard error.

Site	Fertilizer type	Total Biomass	root/shoot	Total seedling nitrogen	Seedling nitrogen root/shoot
		g seedling^{-1}	g g^{-1}	g seedling^{-1}	g g^{-1}
Wilson	CONV	21.01 (2.73)	2.14* (0.33)	0.19 (0.03)	2.39** (0.21)
	CRF	14.61 (3.40)	3.19* (0.28)	0.19 (0.04)	4.27** (0.44)
Hayward	CONV	9.83 (1.27)	3.41 (0.13)	0.19 (0.04)	5.47 (1.61)
	CRF	9.34 (0.38)	3.22 (0.37)	0.16 (0.01)	3.44 (0.47)

* statistical significance at 0.1 within each site

** statistical significance at 0.05 within each site

Fertilizer nitrogen and net-nitrogen mineralization compose the majority of nitrogen input to plant-available nitrogen in the bare-root nursery soil (Table 2). Net-nitrogen mineralization shows a trend of less net mineralization under CRF management than under CONV management by approximately 60% regardless of site difference. Similarly, nitrogen leaching from the bare-root nursery system is mainly influenced by fertilizer type regardless of site difference. CRF management reduces N leaching by 70% at Wilson and by 40% at Hayward.

Table 2. Nitrogen budget analysis of conventional fertilizer management (CONV) and controlled-release fertilizer management (CRF) at bare-root tree nursery systems in Wilson and Hayward, Wisconsin during the 2005 growing season (May through October).

Site	Fertilizer type	Input			Output	
		Precipitation / irrigation	Fertilizer nitrogen	Net nitrogen mineralization	Seedling nitrogen uptake	Nitrogen leaching
		kgN ha^{-1} year^{-1}				
Wilson	CONV	8	192	166	180	186
	CRF	8	163	59	180	50
Hayward	CONV	16	192	55	180	83
	CRF	16	163	20	150	49

Discussion

Oak seedlings use plant available nitrogen in soil more effectively under CRF management than CONV management. CRF management resulted in less fertilizer nitrogen input during a growing season yet produced similar seedling biomass as CONV management in this experiment. Similar effective nutrient use in plant growth under CRF management has been reported for several tree species at container-grown tree nurseries (Irino et al., 2004; Sandrock et al., 2005) and agricultural fields (Shoji and Kanno, 1994; Guertal, 2000; Shoji et al., 2001).

CRF management produces higher quality seedlings than CONV management if the field receives sufficient precipitation or irrigation. Although the size of seedling is similar, more nutrients in the root system should improve post-transplant growth (Malik and Timmer, 1995; Salifu and Timmer, 2003; Birge et al., 2006). This experiment shows the higher nitrogen accumulation in roots at the Hayward nursery, but this is presumably caused by a severe drought in the Hayward area from July through early September 2005. Even though the Hayward nursery had an intense irrigation schedule during that time, the seedlings at Hayward still grew under water stress (data not shown). In this drought condition, it appears there was insufficient water to leach plant-available nitrogen from soil profile under CONV management, even though the soil texture is very sandy. Therefore, the seasonal dynamics of plant-available nitrogen in soil under CONV management at the Hayward could be similar dynamics with the CRF management.

CRF management reduced nitrogen leaching regardless of site difference, likely due to less input of fertilizer nitrogen and net-nitrogen mineralization during the growing season and better timing of nitrogen application than CONV management. Less nitrogen leaching under CRF management has been reported for container-grown nurseries (Cox, 1993; Cabrera, 1997; Fernandez-Escobar et al., 2004) and agricultural fields (Shoji et al., 2001; Morita et al., 2002; Zvomuya et al., 2003) due to the better matching of fertilizer nitrogen input and plant demands. The less net-nitrogen mineralization under CRF management indicates greater soil microbial activity than CONV management. Nitrification activity under CRF management is less than CONV management for a short time period, but sustains at the activity rate for a longer time period than CONV (Chu et al., 2005). Although this study could not reveal the detailed fate of fertilizer-nitrogen in the bare-root nursery soils, it seems dynamic relationships occur among differences of fertilizer inputs, soil plant-available nitrogen-pool, and net-nitrogen mineralization.

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Reference

Alva, A.K. 1992. Differential leaching of nutrients from soluble vs. controlled-release fertilizers. Environ. Mgmt. 16:769-776.

Alva, A.K., A. Fares, and H. Dou. 2003. Managing citrus trees to optimize dry mass and nutrient partitioning. J. Plant Nutr. 26:1541-1559.

Alva, A.K., S. Paramasivam, T.A. Obreza, and A.W. Schumann. 2006. Nitrogen best management practice for citrus trees–I. Fruit yield, quality, and leaf nutritional status. Scientia Horticulturae 107:233-244.

Birge, Z.K.D., K.F. Salifu, and D.F. Jacobs. 2006. Modified exponential nitrogen loading to promote morphological quality and nutrient storage of bareroot-cultured *Quercus rubra* and Quercus alba seedlings. Scand. J. Forest Res. 21:306-316.

Borken, W., Y.J. Xu, and F. Beese. 2004. Ammonium, nitrate and dissolved organic nitrogen in seepage water as affected by compost amendment to European beech, Norway spruce, and Scots pine forests. Plant Soil 258:121-134.

Broschat, T.K., and K.A. Moore. 2001. Influence of substrate and fertilizer analysis and rate on growth and quality of five species of bedding plants. Horttechnology 11:434-437.

Brye, K.R. 1999. Carbon and nitrogen budget evaluation of natural and managed ecosystems. Ph.D diss., University of Wisconsin - Madison, Madison, WI.

Cabrera, R.I. 1997. Comparative evaluation of nitrogen release patterns from controlled-release fertilizers by nitrogen leaching analysis. Hortscience 32:669-673.

Chu, H.Y., Y. Hosen, K. Yagi, K. Okada, and O. Ito. 2005. Soil microbial biomass and activities in a Japanese Andisol as affected by controlled release and application depth of urea. Biol. Fertil. Soils 42:89-96.

Cox, D.A. 1993. Reducing nitrogen leaching-losses from containerized plants–the effectiveness of controlled-release fertilizers. J. Plant Nutr. 16:533-545.

Dey, D.C., and W.C. Parker. 1997. Morphological indicators of stock quality and field performance of red oak (*Quercus rubra* L.) seedlings underplanted in a central Ontario shelterwood. New Forests 14:145-156.

Fernandez-Escobar, R., M. Benlloch, E. Herrera, and J.M. Garcia-Novelo. 2004. Effect of traditional and slow-release N fertilizers on growth of olive nursery plants and N losses by leaching. Scientia Horticulturae 101:39-49.

Guertal, E.A. 2000. Preplant slow-release nitrogen fertilizers produce similar bell pepper yields as split applications of soluble fertilizer. Agron. J. 92:388-393.

He, Z.L., D.V. Calvert, A.K. Alva, D.J. Banks, and Y.C. Li. 2003. Thresholds of leaf nitrogen for optimum fruit production and quality in grapefruit. Soil Sci. Soc. Am. J. 67:583-588.

Imo, M., and V.R. Timmer. 1992. Growth, nutrient allocation and water relations of mesquite (Prosopis-Chilensis) seedlings at differing fertilization schedules. Forest Ecol. Mgmt. 55: 279-294.

Irino, K.O., Y. Iba, S. Ishizuka, T. Kenzo, S. Ripot, J.J. Kendawang, N. Miyashita, K. Nara, T. Hogetsu, I. Ninomiya, K. Iwasaki, and K. Sakurai. 2004. Effects of controlled-release fertilizer on growth and ectomycorrhizal colonization of pot-grown seedlings of the dipterocarp Dryobalanops lanceolata in a tropical nursery. Soil Sci. Plant Nutr. 50:747-753.

Jaber, F.H., S. Shukla, P.J. Stoffella, T.A. Obreza, and E.A. Hanlon. 2005. Impact of organic amendments on groundwater nitrogen concentrations for sandy and calcareous soils. Compost Sci. Util. 13:194-202.

Jacobs, D.F., K.F. Salifu, and J.R. Seifert. 2005. Relative contribution of initial root and shoot morphology in predicting field performance of hardwood seedlings. New Forests 30:235-251.

Juntunen, M.L., T. Hammar, and R. Rikala. 2003. Nitrogen and phosphorus leaching and uptake by container birch seedlings (*Betula pendula* Roth) grown in three different fertilizations. New Forests 25:133-147.

Kirchmann, H., and L. Bergstrom. 2001. Do organic farming practices reduce nitrate leaching? Commun. Soil Sci, Plant Anal. 32:997-1028.

Kormanik, P.P., S.J.S. Sung, D.J. Kass, S. Schlarbaum, and T.A. Waldrop. 1998. Effect of seedling size and first-order-lateral roots on early development of northern red oak on mesic sites. p. 247-252. In General Technical Rep., Southern Res. Stn., USDA Forest Service.

Malik, V., and V.R. Timmer. 1995. Interaction of nutrient loaded black spruce seedlings with neighboring vegetation in greenhouse environments. Can. J. Forest Res. 25:1017-1023.

Morita, A., H. Takano, M. Oota, and T. Yoneyama. 2002. Nitrification and denitrification in an acidic soil of tea (*Camellia sinensis* L.) field estimated by delta N-15 values of leached nitrogen from the soil columns treated with ammonium nitrate in the presence or absence of a nitrification inhibitor and with slow-release fertilizers. Soil Sci. Plant Nutr. 48:585-593.

Salifu, K.F., and V.R. Timmer. 2003. Nitrogen retranslocation response of young *Picea mariana* to nitrogen-15 supply. Soil Sci. Soc. Am. J. 67:309-317.

Sandrock, D.R., A.N. Azarenko, and T.L. Righetti. 2005. Fertilization of two container-grown woody ornamentals based on their specific nitrogen accumulation patterns. Hortscience 40: 451-456.

Shaviv, A. 2001. Advances in controlled-release fertilizers. Adv. Agronomy 71:1-49.

Shoji, S., and H. Kanno. 1994. Use of polyolefin-coated fertilizers for increasing fertilizer efficiency and reducing nitrate leaching and nitrous oxide emissions. Fert. Res. 39:147-152.

Shoji, S., J. Delgado, A. Mosier, and Y. Miura. 2001. Use of controlled release fertilizers and nitrification inhibitors to increase nitrogen use efficiency and to conserve air and water quality. Commun. Soil Sci. Plant Anal. 32:1051-1070.

Thompson, J.R., and R.C. Schultz. 1995. Root system morphology of *Quercus rubra* L. planting stock and 3-year field performance in Iowa. New Forests 9:225-236.

Timmer, V.R. 1997. Exponential nutrient loading: A new fertilization technique to improve seedling performance on competitive sites. New Forests 13:279-299.

Zvomuya, F., C.J. Rosen, M.P. Russelle, and S.C. Gupta. 2003. Nitrate leaching and nitrogen recovery following application of polyolefin-coated urea to potato. J. Environ. Qual. 32:480-489.

PERFORMANCE OF NEW CORN NITROGEN RATE GUIDELINES

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Introduction

In fall 2005 the Department of Soil Science unveiled a nitrogen (N) rate guideline tool to aid producers in determining a N fertilizer rate for corn that is appropriate for their economic situation. This tool is called the maximum return to nitrogen (MRTN) approach. MRTN will be described briefly; for more details please see Laboski et al. (2006) and Laboski (2006).

The new N rate guidelines for Wisconsin are provided in Table 1. In order to determine the N application rate using this table, one must first know:

- ✓ Soil yield potential. All soils in Wisconsin have been classified into yield potential categories based on the soil's rooting depth, water holding capacity, drainage, and length of growing season. Soil yield potentials can be found in UWEX publication A2809 "Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin."
- ✓ Previous crop.
- ✓ N:corn price ratio. This is the price of N per pound divided by the price of corn per bushel.

Using these three pieces of information, an N rate can be identified that will, on average, maximize economic return to N (MRTN). A range of N rates that will produce economic profitability within one dollar per acre of the maximum can also be identified. Guidelines for choosing which part of the range to use are provided in the list below.

- If there is > 50% residue cover at planting, use the upper end of the range.
- When corn follows small grains on medium and fine textured soils, the mid-to-low end of the profitable range is most appropriate.
- If 100 % of the N will come from organic sources, use the top end of the range. In addition, up to 20 lb N/a in starter fertilizer may be applied in this situation.
- For medium and fine textured soils with: < 2% organic matter, use the high end of the range; > 10 % organic matter, use the low end of the range.
- For coarse textured soils with: < 2% organic matter, use the high end of the range; > 2 % organic matter, use the mid to low end of the range.
- If a medium yield potential soil is irrigated, use the rates suggested for high yield potential soils.
- If there is a likelihood of residual N (carry over N), then use the low end of the range or use the high end of the range and subtract preplant nitrate test (PPNT) credits.

In early 2006 with high N fertilizer prices and less than desirable corn prices, many farmers were interested in using the MRTN approach as a means to improve economic profitability. However, because the concept was new many were reluctant to fully embrace the approach, but were interested in trying it. Thus, in 2006 many on-farm plots were established throughout the state with the objective to verify the performance of the MRTN approach.

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Table 1. Suggested N application rates for corn at different N:corn price ratios.

Soil and previous crop	N:corn price ratio ($/lb N:$/bu)			
	0.05	0.10	0.15	0.20
	lb N/a (Total to Apply)[3]			
HIGH/V. HIGH YIELD POTENTIAL SOILS				
Corn, Forage legumes, Leguminous vegetables, Green manures[4]	165[1] (135-190)[2]	135 (120-155)	120 (100-135)	105 (90-120)
Soybean, Small grains[5]	140 (110-160)	115 (100-130)	100 (85-115)	90 (70-100)
MEDIUM/LOW YIELD POTENTIAL SOILS				
Corn, Forage legumes, Leguminous vegetables, Green manures[4]	120 (100-140)	105 (90-120)	95 (85-110)	90 (80-100)
Soybean, Small grains[5]	90 (75-110)	60 (45-70)	50 (40-60)	45 (35-55)
IRRIGATED SANDS AND LOAMY SANDS				
All crops[4]	215 (200-230)	205 (190-220)	195 (180-210)	190 (175-200)
NON-IRRIGATED SANDS AND LOAMY SANDS				
All crops[4]	120 (100-140)	105 (90-120)	95 (85-110)	90 (80-100)

[1] Rate is the N rate that provides the maximum return to N (MRTN).
[2] Range is the range of profitable N rates that provide an economic return to N within $1/a of the MRTN.
[3] These rates are for total N applied including N in starter fertilizer and N used in herbicide applications.
[4] Subtract N credits for forage legumes, leguminous vegetables, green manures, and animal manures. This includes 1st, 2nd, and 3rd year credits where applicable. Do not subtract N credits for leguminous vegetables on sand and loamy sand soils.
[5] Subtract N credits for animal manures and 2nd year forage legumes.

Methods and Materials

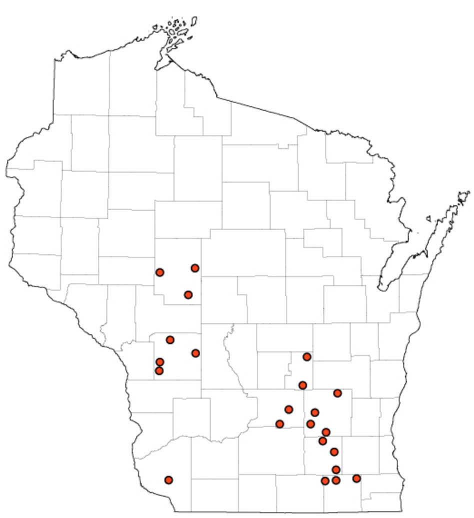

Figure 1. Location of the 22 MRTN on-farm verification plots in 2006.

University of Wisconsin faculty and staff were involved in conducting these on-farm plots in cooperation with participating farms. Twenty-two plots were located throughout the state (Figure 1). Soybean was the previous crop for 13 locations and corn for nine locations (Table 2). Very high, high, and medium yield potential soils were represented along with non-irrigated sands/loamy sands.

Site selection criteria included:

a) Previous crops: corn, soybean, vegetable crops, or small grains.
b) Avoid sites with first or second year corn after alfalfa or a forage legume.
c) Avoid sites where manure or other organic N sources have been applied in the last three years.
d) Uniform soils typically used for corn production.

The experimental design was a randomized complete block with three replications. The plot size was flexible in that any number of rows or length was acceptable. However, the harvested area was the same for all replications at a location. The treatments were: medium yield potential soils (MYPS): 0, 40, 80, 120, 160 lb N/a; high yield potential soils (HYPS): 0, 40, 80, 120, 160, 200 lb N/a. Nitrogen source, application method, and application timing were chosen to minimize N losses at each site (Table 2).

An adapted corn hybrid was planted at each site. Routine soil samples were collected prior to planting and analyzed for P, K, pH, and organic matter (OM). Preplant nitrate (PPNT) samples were also collected to a depth of two feet.

Site characteristics such as county, soil yield potential, soil name, OM content, surface residue at planting, tillage, and PPNT N credit are provided in Table 2. Sites 14, 16, 20, and 21 were tile drained. No sites were irrigated. Three sites had a history of manure application within three years prior to the study year. Site 3 had 6,000 gal/a of manure applied the first and second year prior to the study; site 15 had 5 T/a of manure applied the second and third year prior to the study; and site 31 had 1,530 gal/a applied the third year prior to the study.

Grain yield response to N fertilizer was fit with quadratic plateau, linear plateau, and quadratic models. The model with the best R^2 was chosen to represent the yield response. The economic optimum N rate (EONR) for each site was calculated based on N:corn price ratios of 0.05, 0.10, and 0.15. For all price ratios the price of corn was set at $3.00/bu and the price of N varied: $0.15/lb, $0.30/lb, and $0.45/lb for 0.05, 0.10, and 0.15 price ratios, respectively. Performance of MRTN was assessed by using the yield response function to determine the yield that would have been obtained if different N rates were applied.

Results and Discussion

Maximum grain yield and the amount of N needed to reach that yield is given in Table 2 and Figure 2. Figure 2 shows that using a yield goal approach for making a N recommendation for maximum yield most often results in over application of N and subsequently results in an economic loss to the grower. Additionally, fertilizing for maximum yield is not profitable because there are diminishing returns on the last increments of N applied.

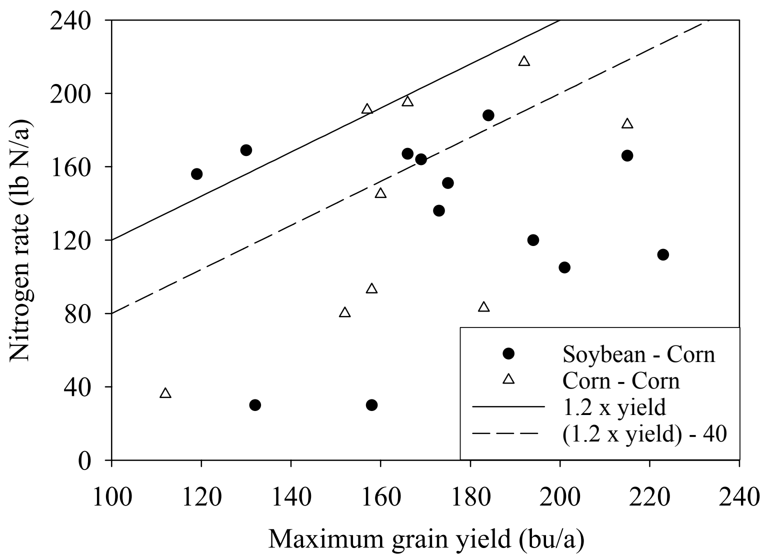

Figure 2. Nitrogen rate needed to obtain maximum grain yield. The lines represent the N application rate recommendation that results from using a yield goal based approach for both corn after corn (1.2 x yield) and corn after soybean (1.2 x yield – 40).

The economic optimum N rate (EONR) is the N rate where the net return on the investment in N is maximized. The yield at EONR can be less than the maximum yield, but depends upon the shape of the response curve for a field and the N:corn price ratio that is being considered. The effectiveness of the MRTN approach in accurately predicting the EONR for each site for 0.05, 0.10, and 0.15 N:corn price ratios is provided in Tables 3, 4, and 5, respectively. In the comparisons, the MRTN N rate was chosen based upon soil yield potential, previous crop, and the guidelines for selecting which portion of the MRTN range to use. Thus, if a site was no tilled or had greater than 50 % residue cover the top end of the range was chosen for the comparison as opposed to the actual MRTN rate. This distinction is import because it represents the decision that a grower would make based on Table 1 and the guidance points that follow.

In Tables 3 to 5, the MRTN N rate for each N:corn price ratio is provided along with the yield obtained at the N rate. This is compared to the observed EONR for each site at the same N:corn price ratio. The columns labeled "Difference (MRTN – EONR)" are the difference in N rate and yield obtained for each N rate; a negative number in either of these columns indicates that the MRTN approach would have resulted in an under application of N and yield loss, while a positive number indicates that MRTN would have resulted in an over application of N and sometimes a slight increase in yield. The economic column is the economic loss caused by either under or over application of N; whereby both yield lost/gained and cost of N applied or not applied are factored in.

For all sites, N was under applied 41, 50, and 55% of the time for the 0.05, 0.10, and 0.15 price ratios, respectively. For corn following soybean N was under applied 38, 46, and 54% of the time for the 0.05, 0.10, and 0.15 price ratios, respectively; while for corn following corn N was under applied 45, 56, and 56% of the time for the 0.05, 0.10, and 0.15 price ratios, respectively. Greater economic loss occurred because of over application of N compared to under application (Table 3) at the 0.05 price ratio. The economic loss caused by under or over application of N is balanced at the 0.10 and 0.15 price ratios (Tables 4 and 5). Overall the MRTN approach provides an N rate that is on average balancing economic losses and, thus, maximizing return on the investment in N fertilizer.

In the previous comparison, single N rates were compared to each other. Another way to compare each site's EONR with MRTN is determine how often the EONR was within the MRTN range for each price ratio. At the 0.05 price ratio, the MRTN range encompassed the EONR 46% of the time, was greater than the MRTN range 27% of the time, and was less than the MRTN range 27% of the time. The MRTN range encompassed the EONR 14 and 18 % of the time for the 0.10 and 0.15 price ratios, respectively. Fifty-four and 44% of the time EONR was greater than the MRTN range for the 0.10 and 0.15 price ratios, respectively. The MRTN range was greater then EONR 32 and 36% of the time for the 0.10 and 0.15 price ratios, respectively. For each site, if a range of N rates that produces an economic return within $1/a of the EONR were calculated, the range would often over lap with the published MRTN range.

Growers are often concerned with yield loss from reduced N rates. Table 6 provides relative yield obtained using the MRTN approach at each N:corn price ratio, where relative yield is defined as the yield obtained as a percent of the maximum yield at the site. The average relative yield over all sites at the 0.05 price ratio is 99% with a range of 97 to 100%. As the price ratio increases, the average relative yield decreases to 97 % at the 0.15 price ratio. When using MRTN to reduce N rates in an effort to improve profitability, there is a risk for yield loss. At the 0.15 price ratio, often (45% of the time) that loss is small (0 to 1%) and infrequently (14% of the time) the loss is greater (9 to 11%).

If the preplant nitrate test (PPNT) is used to adjust N rates, over applications of N at the 0.05 price ratio can be reduced. However when N rates are already being reduced with the 0.10 and 0.15 price ratios, using the PPNT to further reduce N rates would often result in under application of N at the sites in this database.

For all three sites that had a manure history, the MRTN N rate would have resulted in an over application of N. At site 3, which was a sandy site, there was no PPNT credit, hence there was no way to predetermine that this site would have a minimal yield response to N. For site 31 there was a 19 lb N/a credit; taking that credit would have reduced the amount of N that was over applied, but over application would have still occurred. The PPNT was not taken for site 15.

Conclusions

These data are likely quite representative of the range of response to applied N that occurs on Wisconsin farms because the data set represents a range of soils, use of field scale equipment, and typical grower practices. When evaluating these data, it must be kept in mind that these are the results from just one year at each site. Year-in and year-out the EONR, for a given price ratio, will vary at a location. Until soil N mineralization can be accurately predicted, it will continue to be difficult to predetermine the exact amount of N that will be needed by a corn crop in a given year. The power of the MRTN approach is that it pulls data from multiple locations over multiple years to arrive at a best estimate of profitability by balancing economic losses from over and under application of N.

Acknowledgments

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References

Laboski, C.A.M. 2006. Implementation of regional nitrogen fertilization guidelines for corn in Wisconsin. *In* Proc. 2006 Wis. Fert., Aglime, and Pest Mgmt. Conf. 45:77-82..

Laboski, C.A.M., J.B. Peters, and L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable and fruit crops in Wisconsin. UWEX Publ. A2809. Univ. of Wisconsin-Extension, Madison, WI.

Table 2. Previous crop, soil yield potential, county, and soil name/texture, soil organic matter content (OM), N source, N application method, N timing, tillage, surface residue cover at planting, preplant nitrate test (PPNT) N credit, plateau N rate (PNR) and corn yield at PNR (max. yield) for 22 on-farm MRTN evaluation trials in Wisconsin, 2006.

Soil yield potential	County	Site i.d.	Soil name and texture †	OM	N Source §	N application method ¶	N application timing	Tillage*	Residue	PPNT N credit	PNR	Yield @ PNR
				%					%	lb N/a	lb N/a	bu/a
PREVIOUS CROP = SOYBEAN												
Very high	Monroe	1	Jackson sil	3.5	AA	Sub-Surf	Sidedress	NT	70	7	136	173
	Monroe	4	Downs sil	2.0	AA	Sub-Surf	Sidedress	NT	55	1	167	166
	Walworth	16	Plano sil	3.9	UAN-28	Sub-Surf	Sidedress	NT	50	3	120	194
	Dodge	20	Pella sicl	3.8	AA	Sub-Surf	Sidedress	CP F	5	20	105	201
	Columbia	24	Plano sil	3.4	UAN-28	SB/Inc	Preplant	CP F	10	31	112	223
High	Green Lake	9	Kidder fsl	1.8	AA	Sub-Surf	Sidedress	Yes	n.d. #	0	151	175
	Jefferson	14	Keowns sil	4.7	UAN-28	Sub-Surf	Sidedress	NT	50	0	164	169
	Walworth	17	Dodge sil	1.6	UAN-28	Sub-Surf	Sidedress	NT	45	0	188	184
Medium	Clark	5	Withee sil	3.6	AN	SB/NoInc	Preemerge	D S	30	37	30	158
	Clark	6	Flambeau l	3.2	AN	SB/NoInc	Preemerge	D S	30	0	30	132
Non irrigated	Monroe	2	Tarr s	0.7	AA	Sub-Surf	Sidedress	D S	15	0	156	119
Sands &	Monroe	3	Impact s	1.1	AA	Sub-Surf	Sidedress	NT	n.d.	0	169	130
Loamy sands	Columbia	23	Salter ls	1.4	UAN-28	Sub-Surf	Sidedress	CP F	40	0	166	215
PREVIOUS CROP = CORN												
Very high	Walworth	15	Plano sil	2.5	UAN-28	Sub-Surf	Sidedress	CP F	30	n.d.	93	158
	Dodge	21	Mayville sil	2.3	UAN-32	Sub-Surf	Sidedress	CP F	30	0	195	166
	Dodge	22	Elburn sil	2.5	UAN-28	Sub-Surf	Sidedress	D S	10	18	191	157
	Grant	31	Rozetta sil	2.3	Urea	SB/Inc	Preplant	CP F	25	19	83	183
High	Green Lake	10	Kidder l	1.6	Urea-I	SB/NoInc	Sidedress	NT	n.d.	0	217	192
	Dodge	19	Mendota sil	3.2	UAN-28	Sub-Surf	Preemerge	NT	80	35	183	215
Medium	Clark	8	Flambeau l	3.2	AN	SB/NoInc	Preemerge	DT F	25	9	36	112
	Jefferson	12	Wasepi sl	5.6	UAN-28	Sub-Surf	Preemerge	CP F	35	0	145	160
	Jefferson	13	Wasepi sl	5.6	UAN-28	Sub-Surf	Sidedress	CP F	35	0	80	152

† VH, very high; H, high; M, medium; s/ls, sands and loamy sands non-irrigated.
‡ sil, silt loam; sicl, silty clay loam; fsl, fine sandy loam; l, loam; ls, loamy sand; s, sand; sl, sandy loam.
§ AA, anhydrous ammonia; UAN, urea-ammonium nitrate; AN, ammonium nitrate; Urea-I, urea with Agrotain.
¶ Sub-Surf, subsurface; SB, surface broadcast; Inc, incorporated; NoInc, not incorporated.
* CP F, chisel plow fall; D S, disk spring; DT F, deep till fall; NT, no till; Yes, tillage occurred but not described.
# n.d., not determined

Table 3. MRTN N rate guideline and observed economic optimum N rate (EONR) and yield at MRTN and EONR at the **0.05 N:Corn price ratio** and difference between EONR and MRTN N rate, yield, and economic return for 22 on-farm MRTN trials in Wisconsin, 2006.

Previous crop	Soil yield potential	Site i.d.	MRTN rate guideline		Observed EONR		Difference (MRTN minus EONR)		
			N rate	Yield	N rate	Yield	N rate	Yield	Economic
			lb/a	bu/a	lb/a	bu/a	lb/a	bu/a	$/a
Soybean	Very high	1	160	173	129	173	31	0	-4.65
		4	160	165	161	165	-1	0	0.15
		16	160	194	115	194	45	0	-6.75
		20	140	201	105	201	35	0	-5.25
		24	140	223	107	223	33	0	-4.95
	High	9	160	175	144	175	16	0	-2.40
		14	160	168	163	169	-3	-1	-2.55
		17	160	182	180	184	-20	-2	-3.00
	Medium	5	90	158	30	158	60	0	-9.00
		6	90	132	30	132	60	0	-9.00
	Sands/loamy sands	2	140	118	151	119	-11	-1	-1.35
		3	140	127	169	130	-29	-3	-4.65
		23	140	213	136	213	4	0	-0.60
Corn	Very high	15	165	158	93	158	72	0	-10.80
		21	165	163	187	166	-22	-3	-5.70
		22	165	156	180	157	-15	-1	0.75
		31	165	183	82	183	83	0	-12.45
	High	10	190	187	217	192	-27	-5	-10.95
		19	190	215	179	215	11	0	-1.65
	Medium	8	120	112	36	112	84	0	-12.60
		12	120	158	138	160	-18	-2	-3.30
		13	120	152	80	152	40	0	-6.00
			Average N rate guideline under applied (n = 9)				-16	-2	-3.40
			Average N rate guideline over applied (n = 13)				44	0	-6.62

Table 4. MRTN N rate guideline and observed economic optimum N rate (EONR) and yield at MRTN and EONR at the **0.10 N:Corn price ratio** and difference between EONR and MRTN N rate, yield, and economic return for 22 on-farm MRTN trials in Wisconsin, 2006.

Previous crop	Soil yield potential	Site i.d.	MRTN rate guideline N rate	MRTN rate guideline Yield	Observed EONR N rate	Observed EONR Yield	Difference (MRTN minus EONR) N rate	Difference (MRTN minus EONR) Yield	Difference (MRTN minus EONR) Economic
			lb/a	bu/a	lb/a	bu/a	lb/a	bu/a	$/a
Soybean	Very high	1	130	173	122	173	8	0	-2.40
		4	130	161	150	165	-20	-4	-6.00
		16	130	194	110	194	20	0	-6.00
		20	115	201	105	201	10	0	-3.00
		24	115	223	101	223	14	0	-4.20
	High	9	130	173	137	174	-7	-1	-0.90
		14	130	163	156	168	-26	-5	-7.20
		17	130	173	172	183	-42	-10	-17.40
	Medium	5	60	158	30	158	30	0	-9.00
		6	60	132	30	132	30	0	-9.00
	Sands/loamy sands	2	120	114	144	118	-24	-4	-4.80
		3	120	126	0	116	120	10	-6.00
		23	120	211	127	212	-7	-1	-0.90
Corn	Very high	15	135	158	93	158	42	0	-12.60
		21	135	155	179	165	-44	-10	-16.80
		22	135	150	169	156	-34	-6	-7.80
		31	135	183	80	183	55	0	-16.50
	High	10	155	179	217	192	-62	-13	-20.40
		19	155	212	170	214	-15	-2	-1.50
	Medium	8	105	112	36	112	69	0	-20.70
		12	105	154	132	159	-27	-5	-6.90
		13	105	152	80	152	25	0	-7.50
			Average N rate guideline under applied (n = 11)				-28	-5.5	-8.24
			Average N rate guideline over applied (n = 11)				38	0.9	-8.81

Table 5. MRTN N rate guideline and observed economic optimum N rate (EONR) and yield at MRTN and EONR at the **0.15 N:Corn price ratio** and difference between EONR and MRTN N rate, yield, and economic return for 22 on-farm MRTN trials in Wisconsin, 2006.

Previous crop	Soil yield potential	Site i.d.	MRTN rate guideline		Observed EONR		Difference (MRTN minus EONR)		
			N rate	Yield	N rate	Yield	N rate	Yield	Economic
			lb/a	bu/a	lb/a	bu/a	lb/a	bu/a	$/a
Soybean	Very high	1	115	172	114	172	1	0	-0.45
		4	115	158	140	163	-25	-5	-3.75
		16	115	194	105	193	10	1	-1.50
		20	100	198	105	201	-5	-3	-6.75
		24	100	223	96	222	4	1	1.20
	High	9	115	170	131	173	-16	-3	-1.80
		14	115	158	149	167	-34	-9	-11.70
		17	115	167	164	182	-49	-15	-22.95
	Medium	5	50	158	30	158	20	0	-9.00
		6	50	132	30	132	20	0	-9.00
	Sands/loamy sands	2	110	111	136	117	-26	-6	-6.30
		3	110	125	0	116	110	9	-22.50
		23	110	210	117	211	-7	-1	0.15
Corn	Very high	15	120	158	93	158	27	0	-12.15
		21	120	148	171	164	-51	-16	-25.05
		22	120	146	158	155	-38	-9	-9.90
		31	120	183	78	183	42	0	-18.90
	High	10	135	173	217	192	-82	-19	-20.10
		19	135	207	160	213	-25	-6	-6.75
	Medium	8	95	112	36	112	59	0	-26.55
		12	95	151	125	158	-30	-7	-7.50
		13	95	152	80	152	15	0	-6.75
			Average N rate guideline under applied (n = 12)				-32	-8.3	-10.20
			Average N rate guideline over applied (n = 10)				31	1.1	-10.56

Table 6. Yield loss incurred by using the MRTN approach at several N:corn price ratios for 22 on-farm MRTN trials in Wisconsin, 2006.

		N: corn price ratio					
		0.05		0.1		0.15	
	PNR yield †	Yield	Relative yield ‡	Yield	Relative yield	Yield	Relative yield
	bu/a	bu/a	%	bu/a	%	bu/a	%
1	173	173	100	173	100	172	99
4	166	165	99	161	97	158	95
16	194	194	100	194	100	194	100
20	201	201	100	201	100	198	99
24	223	223	100	223	100	223	100
9	175	175	100	173	99	170	97
14	169	168	99	163	96	158	93
17	184	182	99	173	94	167	91
5	158	158	100	158	100	158	100
6	132	132	100	132	100	132	100
2	119	118	99	114	96	111	93
3	130	127	98	126	97	125	96
23	215	213	99	211	98	210	98
15	158	158	100	158	100	158	100
21	166	163	98	155	93	148	89
22	157	156	99	150	96	146	93
31	183	183	100	183	100	183	100
10	192	187	97	179	93	173	90
19	215	215	100	212	99	207	96
8	112	112	100	112	100	112	100
12	160	158	99	154	96	151	94
13	152	152	100	152	100	152	100
Average relative yield			99		98		97
Standard deviation of average			0.80		2.39		3.64
Maximum relative yield			100		100		100
Minimum relative yield			97		93		89
Median relative yield			100		99		97

† PNR yield, maximum yield obtained at the site.

‡ Relative yield, yield obtained using the MRTN rate for a given price ratio as a percent of the maximum yield achieved at the site.

IMPROVING NITROGEN USE EFFICIENCY (NUE) IN CORN HYBRIDS

Jeffrey Coultas [1]

Nitrogen use efficiency can be defined as the ratio of grain yield to total nitrogen taken up by the plant. Worldwide NUE for cereal crops is around 33% (Raun and Johnson, 1999), creating an opportunity for improvement. The remainder is unavailable for crop yield and subject to loss from the system. Better utilization of applied and mineralized nitrogen will help address water quality issues while providing greater yield potential. Variation within corn germplasm currently exists for NUE, creating a challenge to release untapped potential in new hybrids. Advances in plant breeding and functional genomics have made it possible to understand how genes may work to enhance nitrogen utilization in corn to improve yield performance. Areas for potential NUE improvement include sensing, uptake, assimilation transport, metabolism and remobilization while maintaining the carbon/nitrogen balance to improve kernel retention and growth. Transgenic products with the potential to improve nitrogen uptake and utilization in corn hybrids are in the early stages of development. Lead events provide more yield per unit input at standard rates of nitrogen fertilization in field trials.

References

Below, F.E., Cazetta, J.O., Seebauer, and J.R. 2000. Carbon/nitrogen interactions during ear and kernel development in maize. *In* Physiology and modeling kernel set in maize. 29:15-24. Crop Science Society of America and American Society of Agronomy, Madison, WI.

Raun, W.R., and G.V. Johnson. 1999. Improving nitrogen use efficiency for cereal production. Agron. J. 91:357–363.

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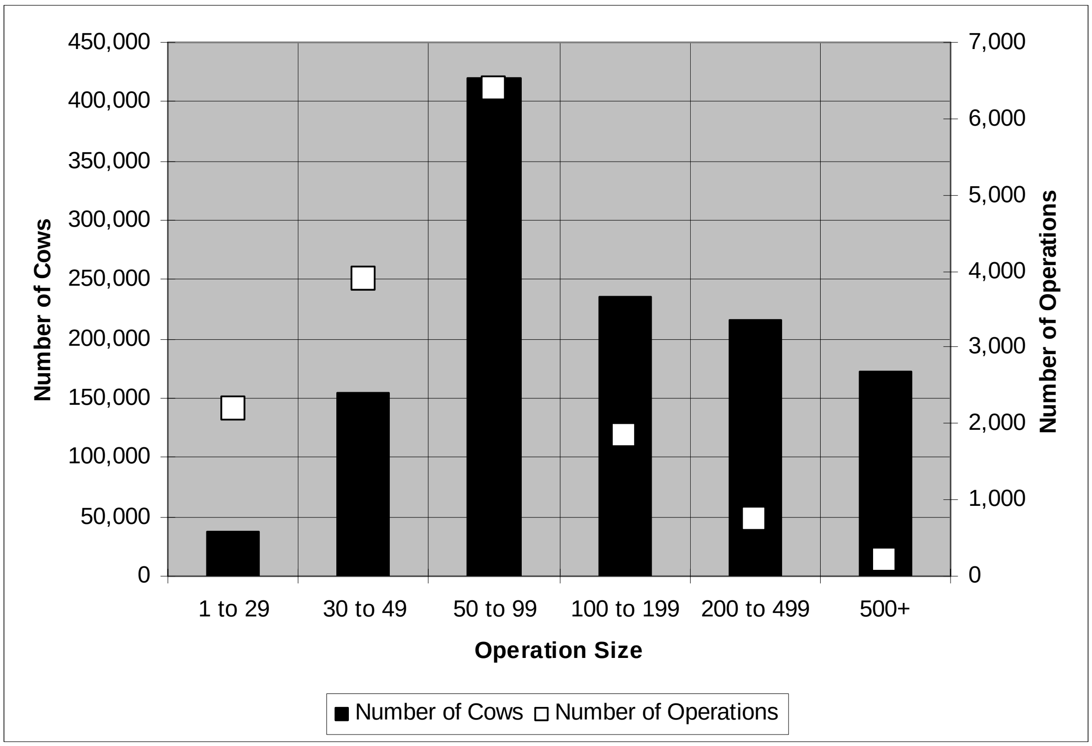
ANAEROBIC DIGESTERS ON WISCONSIN FARMS

John F. Katers[1], Larry Krom[2] and Tucker Burch[3]

Introduction

It is difficult to understate the dairy industry's significance to Wisconsin. It has been estimated by the University of Wisconsin that the dairy industry contributes approximately $20 billion annually to the state's economy and is a key component to the economic well-being of rural communities. As shown in Figure 1, most of Wisconsin's 1.2 million head of dairy cattle reside on operations with a herd size between 50 and 99 head, with the average herd size for Wisconsin dairy farms being just over 80.

Figure 1: Number of dairy farms and dairy cows in Wisconsin by operation size (Source: Wisconsin 2006 Agricultural Statistics, 2005 Numbers).



It can also be seen in Figure 1 that there were at least 200 herds with more than 500 dairy cows operating in the state in 2005, accounting for approximately 173,000 head. These large dairy operations are different from the more traditional smaller farms in many regards. Most notably, they are more capital intensive and tend to concentrate the environmental problems associated with manure management, which often results in increased environmental scrutiny from neighbors and environmental groups regarding issues such as manure storage, odor and land application.

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Anaerobic digestion systems have been increasingly viewed as an attractive option for larger dairy operations, in part because they mitigate some of the previously mentioned environmental issues, such as odor, and also have the potential to provide economic benefits to the farm from electrical generation, the use of digested solids as animal bedding, and other more long-term benefits such as a reduction in greenhouse gases. The capital intensive nature of these larger dairy farms provides a context in which the considerable investment required for an anaerobic digester may be justified, particularly if the digester significantly offsets operating costs or, even better, provides an additional and diversifying new revenue stream. Nationally, the number of digesters has more than doubled over the past two years due to a diverse array of national, state, and local activities to market, cost share and reliably develop operational systems (AgSTAR, 2006). This paper presents a basic overview of anaerobic digestion system technologies and how these technologies have been utilized by Wisconsin dairy farms, as well as potential costs and benefits associated with these systems.

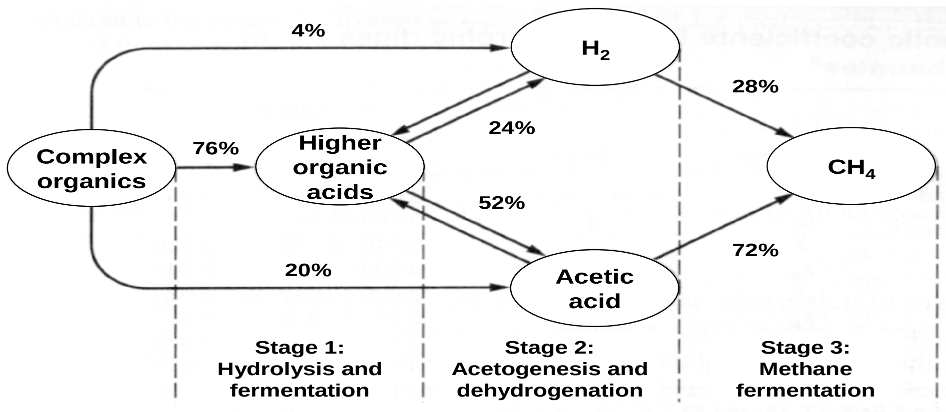
The Anaerobic Digestion Process

Anaerobic digestion can be defined as the biological utilization of organic matter by microbes in an environment in which there is no molecular oxygen. The anaerobic digestion process is thought to occur in three steps, as shown in Figure 2. The first step in the process (hydrolysis) involves the enzyme-mediated transformation of higher molecular-mass compounds into compounds suitable for use as a source of energy and cell carbon. The second step (acetogenesis) involves bacterial conversion of the compounds resulting from the first step into identifiable lower molecular-mass intermediate compounds (like volatile fatty acids). The third step (methanogenesis) involves the bacterial conversion of the intermediate compounds into simpler end products in the form of biogas (Metcalf and Eddy, 1991). The biogas produced during the anaerobic digestion process is typically made up of 55 to 65% methane (CH_4), 35 to 45% carbon dioxide (CO_2), and traces of ammonia (NH_3) and hydrogen sulfide (H_2S). Pure methane is a highly combustible gas that has an approximate heating value of 994 BTU/ft^3 and can be burned in boilers to produce hot water or steam, in engines to power electrical generators, and in absorption coolers to produce refrigeration. Anaerobic digestion may occur at either mesophilic (90° to 105°F) or thermophilic (120° to 135°F) temperature ranges. Digestion at thermophilic temperatures may allow for a higher rate of degradation, which in turn allows for smaller reactors, lower associated capital costs, faster solid-liquid separation, and better control of bacterial and viral pathogens. However, thermophilic systems require more heat to be added to maintain digester operating temperature than mesophilic systems, which can be a significant issue in climates such as that found in Wisconsin.

Types of Anaerobic Digesters

The three most common types of anaerobic digestion systems available for use on dairy farms include covered lagoons, plug flow systems and complete mix systems. Covered lagoons are typically used for large volume, low solids manure and consist of a simple lagoon with an impermeable cover that traps gas generated during the anaerobic decomposition of the manure. Covered lagoons, which are by far the lowest cost systems, are capable of achieving odor reduction, but the amount of energy recovered is minimal and often not enough to justify the capital expenditure for the electrical generation equipment. Covered lagoons often require long detention times of 60 or more days and do not use mixing or temperature control, which makes them particularly sensitive to their local climate, which again would be a potential drawback in Wisconsin. Nationally, covered lagoons account for approximately 20% of all operating farm anaerobic digestion systems, which includes those in start-up and construction (AgSTAR, 2006).

Figure 2: Steps in the anaerobic digestion process (Source: Metcalf and Eddy, 1991).



The second type of digester is referred to as a plug flow digester. This type of system is for high solids manure, which moves through the system in what is considered to be a plug, with little mixing occurring in the system. Plug flow digesters generally operate at mesophilic temperatures (90° to 105°F) and employ a rigid or flexible cover to collect gas. They are temperature controlled with detention times of approximately 15 to 30 days. Solids deposition is a potential problem for plug flow systems if sand or grit get into the system or if the solids content of the manure changes substantially because of seasonal operational issues (e.g., use of summer sprinklers) and drops below approximately 12% solids. Nationally, plug flow anaerobic digestion systems account for approximately 50% of all operating farm anaerobic digestion systems (AgSTAR, 2006).

The final type of anaerobic digester is referred to as a complete mix system. Complete mix anaerobic digestion systems are typically utilized for manure with a solids content of 3 to 10%, which is below what would typically work in a plug flow system. The tanks used for complete mix systems may be installed either above ground or below ground and use temperature control and mixing. Complete mix systems can operate at either mesophilic (90° to 105°F) or thermophilic (120° to 135°F) temperature ranges and generally have detention times of between 15 and 20 days. However, due to their relative complexity, complete mix digesters also have higher capital costs than the other types of anaerobic digestion systems. Additionally, the operation of the mixers used in complete mix systems requires electrical energy which can reduce the net amount of electrical energy produced by the anaerobic digestion system. Nationally, complete mix systems account for approximately 30% of all operating farm anaerobic digestion systems (AgSTAR, 2006).

Although anaerobic digestion has been used successfully for many years by municipal wastewater treatment plants, primarily for stabilization of biosolids prior to land application, operating anaerobic digestion systems as a for-profit activity by other industries has proven to be more difficult. This is primarily related to the high capital costs required for system construction, as well as the relatively low price paid for electricity in many parts of the country, including Wisconsin. It should be noted that in some cases, anaerobic digestion systems can only be considered profitable when other revenue streams, such as using the digested solids for animal bedding and utilizing the engine heat, are included in the analysis. However, not all farmers are willing to use this type of bedding, as many prefer sand bedding or wood shavings, thereby eliminating the bedding as a potential source of revenue. However, it should also be noted that financial incentives available from Focus on Energy in the form of implementation grants for electrical generation and thermal energy recovery, as well as grants available from the U.S. Department of Agriculture, can substantially lower the first costs of these anaerobic digestion systems, which can change the profitability considerably, with some anaerobic digestion systems having a straight-line payback period in the range of 6 to 8 years.

Costs and Benefits

As noted previously, anaerobic digestion systems can be quite costly and are generally found only at larger farms. Capital costs typically account for approximately 90% of the overall anaerobic digestion system costs, with the remaining 10% for preliminary feasibility studies, design and engineering. Approximately 45% of the capital costs are for the electrical generation equipment, 35% for the digester vessel itself, and the remaining 10% for the equalization tank and manure collection systems. The total cost of installed anaerobic digestion systems vary widely and are not always available. This is due to the range of design options, manufacturers, and contractors involved. In Wisconsin, for those systems where data are available the cost is generally between $650 and $1000 per head, with $1000 per head being more common for recently constructed systems (Krom, 2006). As noted previously, a range of grants are available to help offset the initial capital costs of anaerobic digestion system projects.

Despite the relatively high costs associated with anaerobic digesters, a number of significant financial benefits may be realized from installing these systems. While not every project may necessarily take advantage of all of these, typical benefits include: reduction of odor, production of high-quality fertilizer (N, P, and K), reduction of surface and groundwater contamination, destruction of pathogens and weed seeds, reduction of atmospheric methane emissions, and on-farm energy production. Electrical sales and reduced bedding costs represent the two largest sources of revenue for anaerobic digestion systems, particularly as electric utilities implement green power programs or need to meet renewable portfolio standards that exist in many states including Wisconsin. For example, We Energies, Wisconsin's largest utility, received authorization from the Wisconsin Public Service Commission of Wisconsin (PSC) to significantly expand its renewable energy programs. As part of these expanded programs, the PSC approved a new "Biogas Buy-back Rate," which pays $0.08/kWh for on-peak energy and $0.049/kWh for off-peak energy to customers who generate electricity from anaerobic digester technology using waste from animal feeding operations, industrial food processing, or municipal wastewater treatment facilities (AgSTAR, 2006).

It can generally be assumed that a 1000-cow dairy will produce approximately 200 kW of generating capacity, which would be equivalent to approximately 1.5 million kWh/year or 4 kWh/cow/day at a capacity factor of 90% (Krom, 2006). Additionally, the continued implementation of anaerobic digestion systems coupled with cogeneration systems may also increase the potential financial benefits, with the heat used for digester heating, parlor heating, or the heating of other buildings such as greenhouses. The use of the digested solids as animal bedding also represents a significant financial opportunity, although it should be noted that a solid separation system will be required to capture the digested solids and achieve a moisture content that is suitable for use as animal bedding. The benefits of the digested solids used as animal bedding may vary widely, depending on the existing bedding system utilized at the farm, as well as how the bedding is managed. However, it can generally be estimated that bedding costs for a typical farm would be $40-50/cow/year, assuming approximately 3 cubic yards/cow/year, which would be offset by the use of the digested solids as bedding (Krom, 2006). Furthermore, there are also a number of other non-quantified benefits such as odor control that may help farms avoid lawsuits and continue to operate and site new and increasingly larger dairy farms (Kramer, 2005).

Anaerobic Digestion Systems on Wisconsin Farms

Several farm-based anaerobic digestion systems have been constructed in Wisconsin and documented in the *Agricultural Biogas Casebook* (Kramer, 2004), with many more becoming operational or currently under construction since the release of *Agricultural Biogas Casebook*. General information on these Wisconsin farm anaerobic digestion systems can be seen in Table 1.

Table 1: Anaerobic Digesters on Wisconsin Farms.
Sources: Agricultural Biogas Casebook – 2004 Update (Krom, 2006).

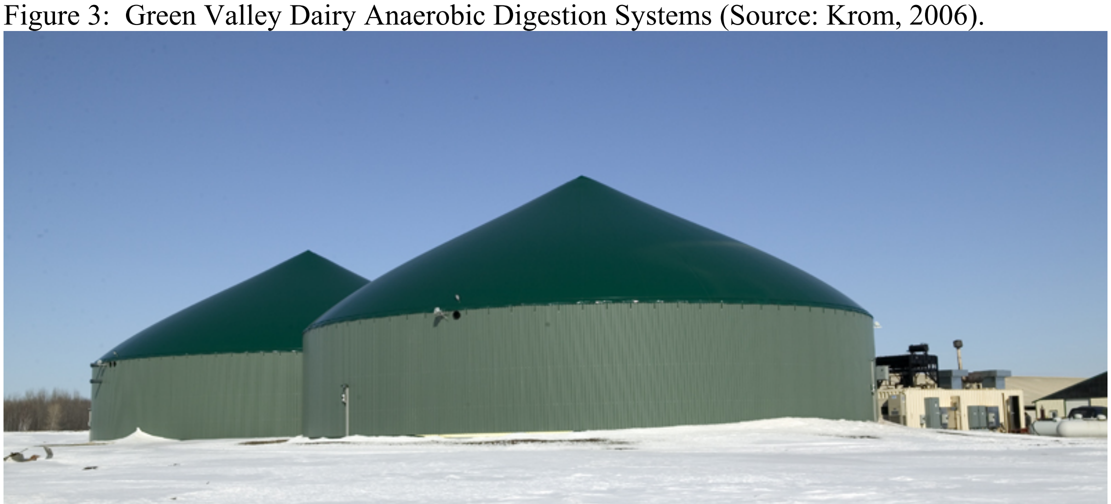
Farm name and location	Farm type head	Digester type	Biogas use	Heat application
Five Star Dairy Elk Mound	Dairy (910)	Microgy complete-mix, thermophilic	Electricity generation	Digester
Wild Rose Dairy LaFarge	Dairy (900)	Microgy complete-mix , thermophilic	Electricity generation	Digester
Baldwin Dairy Baldwin	Dairy (1,225)	Clay-lined lagoon with poly cover (ambient temperature)	Flared, no use	None
Emerald Dairy Emerald	Dairy (1,600)	Poly-lined lagoon with poly cover (ambient temperature)	Flared, no use	None
Double S Dairy Markesan	Dairy (1,100)	Mixed plug-flow loop	Electricity generation	Digester, parlor floor, offices, shop floor
Gordondale Farms Nelsonville	Dairy (850-900)	Mixed plug-flow loop	Electricity generation	Digester, dairy parlor, offices, engine room, warm water flush flume
Stencil Farm Denmark	Dairy (1,000)	Plug-flow mesophilic	Electricity generation	Digester
Quantum Dairy Weyauwega	Dairy (1,200)	Modified plug-flow, mesophilic	Electricity generation	Digester
Vir-Clar Farms Fond du Lac	Dairy (1,350)	Complete-mix, mesophilic	Electricity generation	Digester
Holsum Dairy Hilbert – Irish Rd	Dairy (3,000)	Modified plug-flow, mesophilic	Electricity generation	Digester
Norswiss Digester Elk Mound	Dairy (1,300)	Complete-mix, thermophilic	Electricity generation	Digester
Suring Community Dairy, Suring	Dairy (1,000)	Complete-mix, mesophilic	Electricity generation	Digester
Green Valley Dairy Green Valley	Dairy (2,500)	Complete-mix, mesophilic	Electricity generation	Digester
Lake Breeze Dairy Malone	Dairy (3,000)	Modified plug-flow, mesophilic	Electricity generation	Digester
Holsum Dairy Hilbert – Elm Rd	Dairy (3,000)	Modified plug-flow, mesophilic	Electricity generation	Digester
Clover Hill Dairy	Dairy (1,050)	Modified plug-flow, mesophilic	Electricity generation	Digester
Crave Brothers Farm	Dairy (700 + whey)	Complete-mix, mesophilic	Electricity generation	Digester

The anaerobic digestion systems summarized in Table 1 represent a relatively broad range of design-types and operational arrangements. The following paragraphs describe the unique characteristics of several of the anaerobic digestion systems in Table 1, with digesters having similar design and operational arrangements grouped together.

Anaerobic Digesters in Wisconsin – Complete-mix Mesophilic

Vir-Clar Farms and Green Valley Dairy utilize complete mix, above ground, Biogas Nord digester systems. These systems are constructed as cylindrical concrete tanks, featuring an inner expandable membrane cover under an outer conical top that is kept inflated by positive air pressure. Mixing in these systems is accomplished by several stainless steel propeller blades within the tanks. The Vir-Clar Farm system uses two tanks in series, the first serving as storage for solids and biogas, and the second operating as a mesophilic digester with a retention tine of about 33 days. Enough biogas is produced to power a 350 kW engine-generator at about the 330 kW level. The Green Valley Dairy system operates the two tanks in parallel to accommodate the waste stream of 2,500 dairy cows. Even though enough biogas is produced to power a 600 kW engine-generator, electrical generation is kept at about 550 kW because of capacity limitations in the local electric distribution system. The Green Valley Dairy anaerobic digestion system can be seen in Figure 3.

Figure 3: Green Valley Dairy Anaerobic Digestion Systems (Source: Krom, 2006).



Suring Dairy and Crave Brothers Farm utilize complete mix, above ground, AMBICO digester systems. These systems are constructed similarly to the Biogas Nord systems except they are single tanks constructed from stainless steel. Mixing in the Suring Dairy system is accomplished by several stainless steel propeller blades. The Suring system generates enough biogas to power a 250 kW dual fuel engine generator utilizing about 10% diesel fuel. The Suring Community Dairy anaerobic digestion system can be seen in Figure 4. Mixing in the Crave Brothers Farm system is accomplished by a 45^{o} bladed shaft that extends from outside the tank to the inside bottom of the tank. Co-digestion with 10% whey, from the on-site cheese factory, allows more biogas to be generated than with animal waste alone. The Crave system generates enough biogas to power a 250 kW spark ignition engine-generator fueled by 100% biogas.

Figure 4: Suring Dairy Anaerobic Digestion System (Source: Krom, 2006).

Anaerobic Digesters in Wisconsin – Complete-mix Thermophilic

Five Star Dairy and Wild Rose Dairy use nearly identical digesters and operational arrangements. Each farm has installed a Microgy complete-mix above-ground tank in which the manure flows from top to bottom. The tanks are roughly 40 feet in diameter and 40 feet tall and can hold approximately 660,000 gallons of manure. These systems are designed to operate at thermophilic temperatures (135°F) and have 20 day detention times, although the actual detention times may vary. Additionally, the systems are designed to have small footprints, making them easy to install at existing dairies. Similar digesters have been installed by Microgy on roughly 20 European farms over the last 15 years. The digesters were installed on each farm to take advantage of a variety of benefits including reduced operating costs (through sales of biogas), odor reduction, and weed seed and pathogen control. These farms sell their biogas to Dairyland Power Cooperative, which owns the electricity generation equipment and is responsible for its maintenance on-site. Microgy is also responsible for maintaining the digesters, which are owned by the farms, for the life of the project. Both farms may eventually add local food-grade waste to their digesters and charge tipping fees for accepting these materials. Additionally, Five Star Dairy may sell its digested solids as certified organic fertilizer. Both Five Star Dairy and Wild Rose Dairy expect 10 year payback periods on the digesters (Kramer 2004). Both co-digest 10% fats, oils and grease for operation.

Anaerobic Digesters in Wisconsin – Mixed Plug Flow

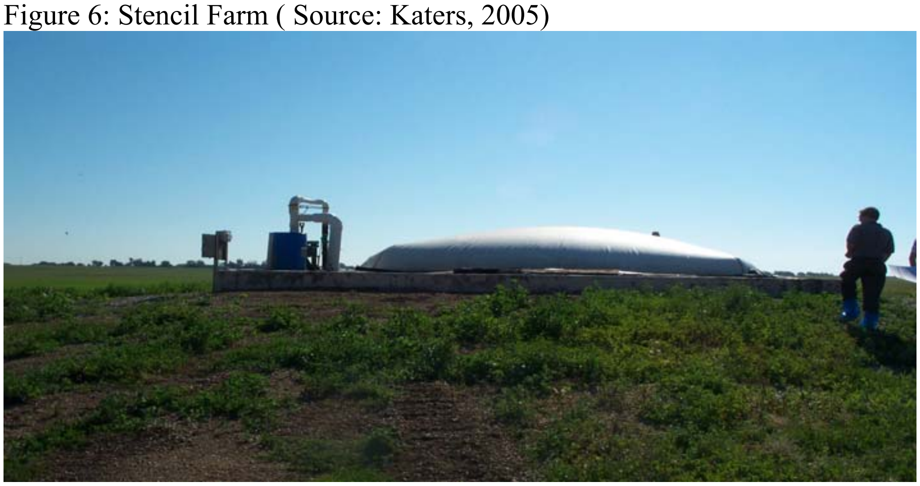
Double S Dairy and Gordondale Farms each use mixed plug-flow digesters. Double S Dairy produces 30,000 gallons of manure per day. Their digester is a two stage (acidogenic and methanogenic) plug-flow system with a fixed cover and an operating temperature of approximately 100°F. The designed detention time is 20 days, but the actual detention time is slightly less. Mixing is accomplished by re-circulating biogas at the bottom of the digester. The digester, which cost $500,000, requires approximately 20 minutes of inspection and maintenance per day. Double S Dairy sells the electricity they produce and also uses the process heat to heat the digester, parlor floor, shop floor, and offices. The digested solids as used as bedding, which saves them an additional $30,000 annually. Gordondale Farms uses a similar two stage digester to handle its approximately 35,000 gallons of manure each day. It has virtually the same vital statistics, although it only cost about $290,000 and is designed to operate at 101°F. The electricity is sold to Alliant Energy, which purchased the electrical generation equipment associated with this anaerobic digestion system at a cost of $230,000, thereby reducing the initial capital costs for the farm. Gordondale Farm earned approximately $23,000 in electricity sales during 2003 and also reported savings in several other areas. In 2003, the farm saved $28,800 by using the digested solids as bedding and avoided $30,000 in commercial fertilizer purchases, $2,000 in propane purchases, and $5,000 in pest control services. The dairy also benefits from odor reduction, which is obviously not a direct economic benefit to the farm, but does have a positive impact on neighbor relations (Kramer, 2004). The Gordondale anaerobic digester can be seen in Figure 5.

Figure 5: Gordondale Farm (Source: Krom, 2006).

Anaerobic Digesters in Wisconsin – Plug Flow

Stencil Farms operates a plug-flow digester that handles approximately 20,000 gallons of manure per day. The digester is a 450,000 gallon combined phase design with a flexible cover and operates at 100°F. The designed detention time is 20 days, though the actual time is 22 to 23 days. The entire system cost approximately $500,000, with benefits achieved from electricity sales, bedding production, high quality fertilizer production and odor reduction (Kramer 2004). The Stencil anaerobic digester can be seen in Figure 6.

Figure 6: Stencil Farm (Source: Katers, 2005)



How Does Wisconsin Compare to Other States

It can be seen in Table 2 that Wisconsin currently leads the nation in both the number of operating farm anaerobic digestion systems, as well as the total energy production in kWh/yr.

Table 2: Anaerobic digester energy production (Source: AgSTAR, 2006).

State	Operating anaerobic digestion systems	Total energy production (1,000 kWh/yr)
Wisconsin	21	72,927
California	18	49,380
New York	13	8,935
Pennsylvania	11	9,966
Iowa	5	3,066
Illinois	4	3,154
Texas	3	19,447

This can be attributed to a number of factors including the collaborative efforts of the Wisconsin Biogas Development Group, the financial and technical assistance available from Focus on Energy, and the cooperation of several Wisconsin utilities. It should also be noted that Wisconsin was one of the first states to start installing a significant number of farm anaerobic digestion systems and, therefore, benefited greatly from the USDA funding that was available through the Renewable Energy and Energy Efficiency Program (U.S. Farm Bill Section 9006). For instance, in 2004 alone nearly $5 million in grants ranging from $180,000 to $500,000 were made available to 19 different anaerobic digestion projects in the state of Wisconsin.

Conclusions

Nationally and in the State of Wisconsin, interest in farm anaerobic digestion systems continues to increase, with Wisconsin currently leading the nation in both the number of installed farm anaerobic digestion systems and the total energy production from these systems. In particular, anaerobic digesters provide excellent economic and operational opportunity for large dairies, which often benefit from economies of scale. Anaerobic digestion systems can not only help mitigate potential environmental problems often associated with these larger farms, but also offset operating costs and expand and diversify the ability of the farm to earn revenue by providing products such as electricity, bedding, and high quality fertilizer. Overall, the success rate of installed systems has been extremely high and is currently lead by a growing number of engineering and equipment supply companies, including the installation of an increasing number of European style systems (AgSTAR, 2006). Given the increased emphasis on green power programs and renewable portfolio standards, it is likely that farm anaerobic digestion systems will continue to be viewed as a long-term source of reliable renewable energy, particularly in states like Wisconsin with a sizable dairy industry and an increasing number of large farms.

References

AgSTAR. *Digesters Continue Accelerating in the U.S. Livestock Market.* United States Environmental Protection Agency: AgSTAR Digest. Winter 2006.

Katers, John. Farm Anaerobic Digesters. Presented at Farm Technology Days on September 22, 2004. Bloomer, WI.

Kramer, Joseph. *Agricultural Biogas Casebook – 2004 Update.* Resource Strategies, Inc. 2004.

Kramer, Joseph. Anaerobic Digesters in the Great Lakes States. Resource Strategies, Inc. Presented March 3, 2005.

Krom, Larry. Wisconsin Farm Anaerobic Digestion Overview. Presented at the First Annual Manure Bio-Conversion Conference on January 31, 2006. Madison, WI.

Metcalf and Eddy *Wastewater Engineering: Treatment, Disposal, and Reuse, 3rd. Ed.;* McGraw Hill: New York, 1991.

Wisconsin Agricultural Statistics Service. *Wisconsin 2006 Agricultural Statistics.* 2006.

ECONOMIC ISSUES OF COMMUNITY DIGESTORS

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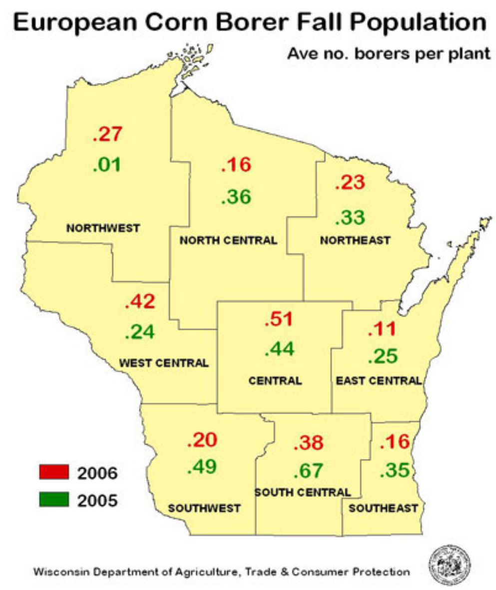
WISCONSIN INSECT SURVEY RESULTS 2006 AND OUTLOOK FOR 2007

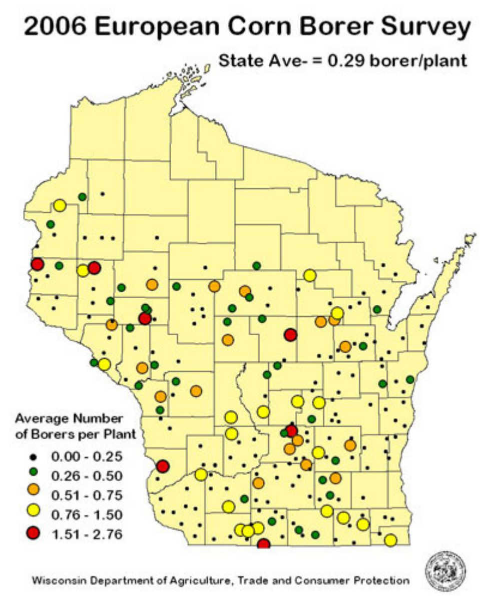
Krista L. Hamilton[1/]

European Corn Borer

Wisconsin's annual fall survey documented a decrease in the state average European corn borer population from 0.40 in 2005 to 0.29 borer per plant in 2006 (29 borers per 100 plants). This compares to a 10-year average of 0.30 and a 50-year average of 0.48 borer per plant. The northwest, west central, and central districts showed increases from 0.01 to 0.27, 0.24 to 0.42, and 0.44 to 0.51 borer per plant, respectively. The largest decreases in 2006 were documented in the south central and southwest districts, where averages declined from 0.67 to 0.38 and 0.49 to 0.20 borer per plant. Lower densities in the southern districts may be associated with increased planting of Bt corn hybrids, although no specific evidence for this hypothesis is available at this time. Testing of field corn for transgenic traits during the summer corn rootworm beetle survey showed the highest utilization of hybrids in the southern three tiers of Wisconsin counties (see map in Corn Rootworm section).



Although district averages were generally low, a total of 20% (45 of 226) of the fields surveyed had populations in excess of 0.50 borer per plant, and 8% (18 of 226) had populations above the economic threshold of 1.0 borer per plant. The west central and central districts in particular had a fair number of fields with economic populations, indicating fields in these regions should be scouted for first generation corn borer injury next June.



European corn borer populations were determined by sampling 25 consecutive stalks in 226 mature corn fields in the districts shown on the accompanying map. Plants were examined for signs of infestation, including broken stalks, exit holes, frass, and larval tunnels. Two plants were dissected to determine the average number of larvae per infested plant. A large majority of the borers were mature and appeared to be in good overwintering condition despite the abundance of rainfall in September. A statewide average of 0.29 borer per plant is comparatively low, suggesting a light first flight of corn borer moths next spring. However, favorable weather next season or a small carryover of parasites could result in an increase of damaging borers.

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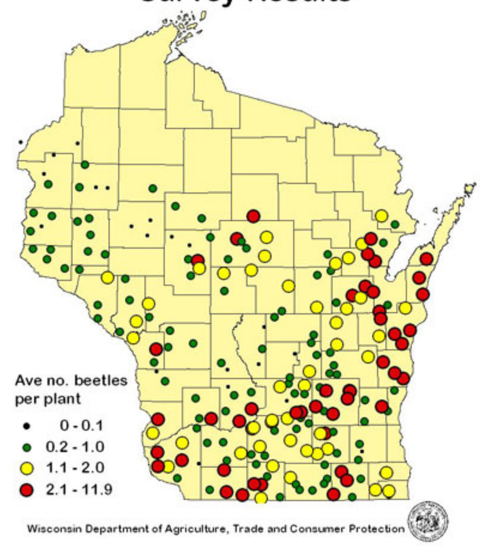
Corn Rootworm

A survey to assess corn rootworm beetle populations during peak beetle emergence last August found a minor decrease in the state average number of beetles per plant, from 1.6 in 2005 to 1.4 in 2006. Results from the statewide survey of corn rootworm adults were as follows: northwest district 0.1 per plant; north central district 0.9 per plant; northeast district 1.8 per plant; west central district 0.8 per plant; central district 0.7 per plant; east central district 2.2 per plant; southwest district 2.2 per plant; south central district 1.7 per plant; southeast district 1.4 per plant.

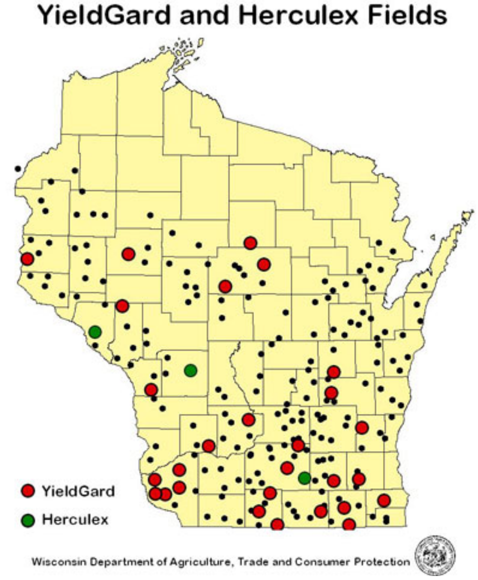
District averages declined from 2005 to 2006 in the northwest, central, southwest, south central and southeast, and increased in the north central, northeast, and east central districts. The most substantial population increases were documented in the northeast, where the average number of corn rootworm beetles per plants rose from 0.3 in 2005 to 1.8 this season, and in the east central district, where the average doubled from 1.1 beetles per plant in 2005 to 2.2 per plant in 2006. A total of 28% (61 of 218) of the sites surveyed had non-economic averages ranging from 0-0.4 beetles per plant, 29% (64 of 218) had averages ranging from 0.5 to 1.0 beetles per plant, and a 43% of the fields had high populations ranging from 1.1 to 11.9 beetles per plant.

2006 Corn Rootworm Beetle Survey Results



Based on 2006 survey findings, multi-year corn in the northeast, east central, and all southern districts is at risk of heavy larval feeding pressure next spring. Averages in the northwest district may have been artificially low because most of the fields checked were drought stressed and had brown silks at the time of the survey. A total of 3% of the fields surveyed were in the dough stage, 6% were in the dent stage, 54% were at maturity (brown silks, cob full size), 34% were in the pollinated stage, and 1% was in the silk emergence stage. Testing for transgenic traits found the YieldGard® Bt-Cry3Bb1 protein in 13% of the fields (28 of 218) surveyed, while the Herculex® Bt-Cry34Ab1 protein was detected in 1% (3 of 218) of the fields checked. A summary table with results of the 2006 corn rootworm beetle survey is shown below.

YieldGard and Herculex Fields



Western Bean Cutworm

Measurable populations of the western bean cutworm, *Loxagrotis albicosta* Smith were detected for the first time in Wisconsin corn fields this season. In late August, Pioneer Hi-Bred

Area Agronomist Arnie Imholte discovered an infestation affecting roughly 15 to 20% of the ears in a field test plot south of Mineral Point, and mature larvae were found feeding in ears in Green, Green Lake, Juneau, and Marquette counties during the European corn borer survey in September and October. Corn ears in many of the fields checked had been partially consumed by either western bean cutworm or corn earworm, but no larvae were present to confirm which species was responsible for the injury. Whether the growing numbers of western bean cutworm sightings are due to an increasing incidence of this pest or increased awareness is not clear. Both are probably contributing factors.

Although its full pest potential remains to be determined, the extensive network of pheromone traps placed throughout the southern two-thirds of the state indicates this insect is most prevalent in western Wisconsin, particularly in the southwest. The accompanying map shows cumulative captures of moths at 135 trapping sites in the southern two-thirds of the state for the period of June 12 to August 28. The highest captures ranging from 100 to 216 moths were reported from Westby in Vernon Co., Mt. Sterling in Crawford Co., Cashton in Monroe Co., and Sylvan in Richland Co. Seven of the 135 sites (5%) registered counts of 51 to 100 moths, another seven sites (5%) had catches of 26-50 moths, and a vast majority, 117 of 135 sites (87%) reported very low cumulative counts of 0-25 moths. These captures represent a significant eastward extension in the known range of this pest, which was historically restricted to the western cornbelt states.

Wisconsin's western bean cutworm population will pass the winter as non-feeding pre-pupae 3 to 9 inches beneath the soil surface and pupate next June. Peak flight activity, based on two years of pheromone trap data, should be anticipated from the third and fourth weeks of July to the first week of August. More survey work is needed to determine the threat of western bean cutworm in Wisconsin. Most of the infestations detected this season were spotty and not particularly severe, and the numbers of moths captured in milk jug traps were very low in comparison to those registered in Illinois and Iowa (ranging up to 1,834 moths). Certainly the potential for this insect to become a major mid- to late-season pest in Wisconsin does exist, but the survey data collected this season are not conclusive enough to reliably shape management decisions at this time.

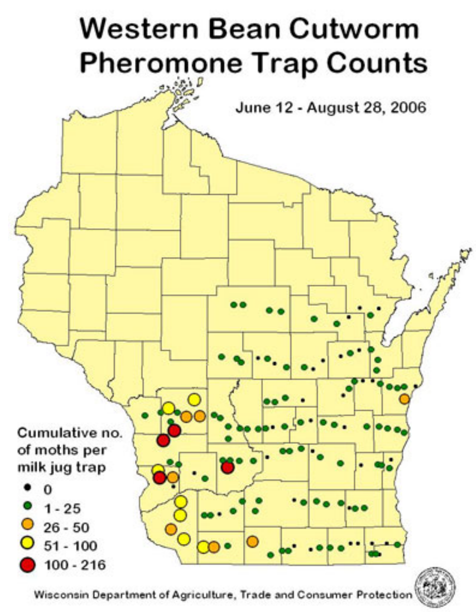
Black Cutworm

Last April a network of 41 traps were placed along Highways 11 and 18 in the southwest corner of the state in anticipation of the arrival

Corn rootworm beetle 2005-2006 survey results.

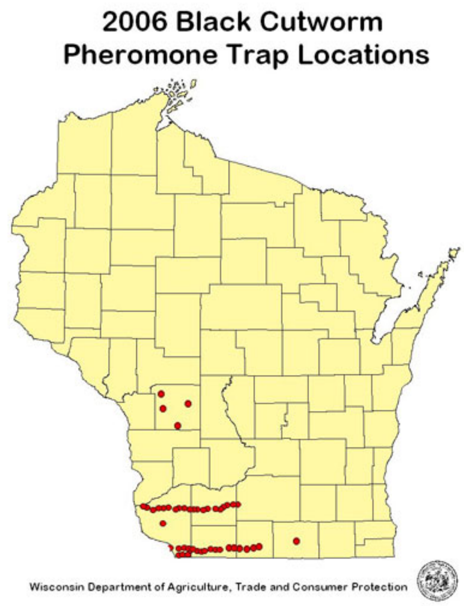
District	*Ave no.CRW per plant 2006*[1]	*Ave no.CRW per plant 2005*[1]	*No. Fields Surveyed 2006*	*No. Fields Surveyed 2005*
Northwest	**0.1**	*0.4*	**15**	*15*
North central	**0.9**	*0.8*	**16**	*15*
Northeast	**1.8**	*0.3*	**10**	*10*
West central	**0.8**	*0.8*	**29**	*31*
Central	**0.7**	*0.9*	**20**	*32*
East central	**2.2**	*1.1*	**27**	*38*
Southwest	**2.2**	*3.2*	**34**	*34*
South central	**1.7**	*1.9*	**48**	*49*
Southeast	**1.4**	*3.8*	**19**	*19*
Statewide Ave.	**1.4**	*1.6*	**218**	*243*

[1]Average based on number of beetles per 10 corn plants examined



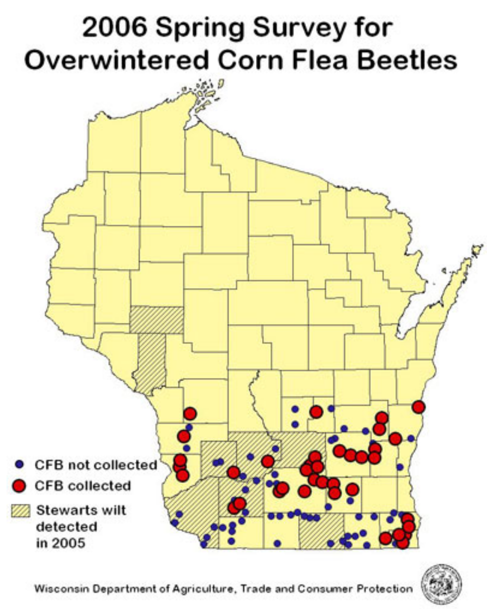
of migratory black cutworm moths from overwintering grounds in southern Louisiana and eastern Mexico. In addition, Bill Veith of Seneca Foods reported counts from Janesville, and Monroe Co. Agent Bill Halfman monitored four traps near Sparta in the west central district. DATCP survey specialists and cooperators have used pheromone traps in 2006 and preceding years to determine the arrival of moths, the start of egg laying, and when seedling corn is most susceptible to cutting.

Black cutworms arrived slightly ahead of schedule this season. The earliest migrants were registered at the Janesville trapping site on April 6, 2006. Other first seasonal moth captures were as follows: April 12 in 2005; April 19 in 2004; April 22 in 2003; April 17 in 2002; and April 21 in 2001. The first "concentrated capture" of eight moths occurred near Janesville on the night of April 24, and corn seedlings were susceptible to cutting by mid-May. Aside from a few isolated instances of cutworm damage to seedling corn in the northwest during the first week of June, this insect cannot be credited with causing any noticeable damage to corn in other parts of the state in 2006.



Corn Flea Beetle

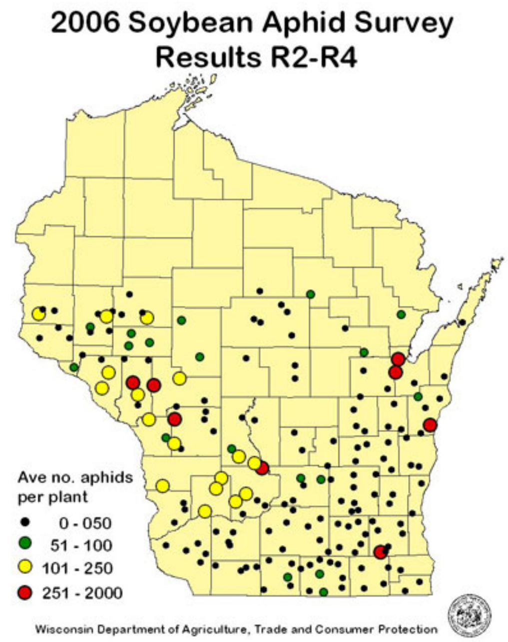
Following a record-setting year of Stewart's wilt detections in Wisconsin seed corn fields in 2005, a spring survey for overwintered corn flea beetles was conducted to forecast the risk for Stewart's wilt in 2006. The Stewart's wilt bacterium, *Pantoea stewartii*, overwinters in the gut of corn flea beetle. If corn flea beetle survives the winter months, generally the bacterium also survives. Surveys for this insect were previously carried out during the 2000-2002 growing seasons, but DATCP specialists questioned their usefulness after the incidence of Stewart's wilt was trace to low for several successive years. The survey was re-established when more cases of Stewart's wilt were detected in 2005 than in any year since 1999. Seed field inspections found the disease in 21 of 44 fields surveyed, or 48% of the fields visited in 2005. The disease occurred in eight counties, extending as far north as Eau Claire County.



Despite the high incidence of Stewart's wilt in 2005, none of the overwintered corn flea beetles collected from 40 of 100 southern and central Wisconsin sites tested positive for the Stewart's wilt bacterium. As expected, the incidence of Stewart's wilt in seed corn fields was very low this season; the disease was found in just three Grant Co. fields earlier this fall.

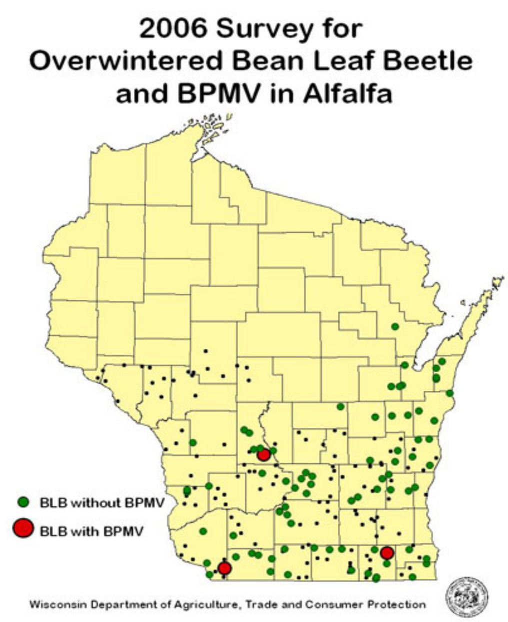
Soybean Aphid

Results from an annual survey of 183 soybean fields (R2 to R4 stages), conducted July 12 to August 9, showed economic populations of aphids did not develop in a majority of Wisconsin soybeans last summer. The survey found 96% (175 of 183 fields) of the soybean fields examined supported aphid populations below the action threshold of 250 aphids per plant, while just 4% (8 of 183) of the fields had soybean aphid populations exceeding the action threshold. Based on the 2006 survey, 85% of the soybean fields averaged fewer than 100 aphids per plant, 10% of the fields averaged 100 to 250 aphids, and 4% averaged 251 to 2,000 aphids per plant. A total of 58% of the fields were at the R2 development stage (full bloom), 20% were at R3 (beginning pod), and 22% were at R4 (full pod). Soybean aphid densities recorded this season were comparable to 2005 densities in most districts, higher than those documented in 2004 (the lightest aphid year on record), and much lower than the record aphid densities detected in 2003. Final survey results are summarized in the map.



Bean Leaf Beetle

Bean pod mottle virus (BPMV) was not prevalent among the 2005-2006 winter survivors, according to a survey conducted between May 4 and June 9. Overwintered beetles were collected from 81 of 202 central and southern Wisconsin first-crop alfalfa fields. Only three beetles from sites in Grant, Juneau, and Walworth Cos. were carriers of BPMV. In addition, none of the 188 soybean leaf samples collected during a summer follow-up survey from July 12 to August 8 tested positive for BPMV, indicating BPMV was probably absent from most Wisconsin fields this season.



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WHEN DOES IT PAY TO PLANT RW Bt CORN IN WISCONSIN?

Carsten D. Croff and Paul D. Mitchell [1/]

Corn rootworm (CRW) is commonly referred to as "the billion dollar bug" as it costs U.S. growers a billion dollars a year in reduced yields and treatment costs (Burchett, 2001). Traditionally, two-year crop rotations were sufficient to control for CRW. However, in recent years a behavioral variant of the western CRW has moved into Wisconsin cornfields. The variant has adapted to traditional crop rotation by laying its eggs in soybeans and other rotated crops, so that economic damage is caused in corn planted the following year. Soil insecticides were commonly used to control CRW in first year corn, but in 2003, rootworm Bt corn became available for western corn rootworm larval control.

Many studies show that, based on measures of root damage, Bt corn provides better control than soil insecticides, but has a higher cost as well. Under moderate or high rootworm pressure, the value of the additional yield saved with Bt corn usually exceeds the higher treatment cost, making Bt corn the more economical of the two treatments. However, many factors affect the economics of using Bt corn. Among the most important, rootworm pressure can vary greatly from year to year, potential yield of fields and regions differ, corn prices and treatment costs also vary. Fields where the rootworm pressure is high will be at greater risk for economic damage from CRW. Likewise, fields that have higher potential yields will suffer larger economic losses under the same CRW pressure than fields with lower potential yields. Higher corn prices will increase the yield value, which will also significantly increase the amount of economic damage caused by CRW. The cost of Bt corn is not as variable as the previous three factors but still has important implications for the economics of Bt corn.

Estimating rootworm pressure relies heavily on surveying methods conducted the previous year. Local and regional rootworm pressure may be estimated, such as using data from surveys conducted by the Wisconsin DATCP (2006). However, CRW pressure varies greatly over landscapes and even within fields. Hence the most accurate method to predict rootworm pressure is to survey each specific field the previous year, either following set scouting protocols or using traps for adults in later summer.

Surveys for the western variant CRW conducted by Cullen (2005) show that the western variant CRW pressure is predominately in the southeastern part of the state, but it varies from field to field and year to year. The most common method of integrated pest management (IPM) consists of using Pherecon AM sticky traps to measure CRW pressure, and then using Bt corn the following year if the CRW trap count as beetles/trap/day (BTD) exceeds the treatment threshold. The alternative is to apply a CRW treatment without measuring the CRW pressure, which may lead to unnecessary treatment, and so excessive cost and profit loss, in years with low CRW pressure. Using UW survey data (Cullen, 2005) and following the conventional yield damage function presented in (Mitchell, 2004), we estimate the profit maximizing CRW threshold (BTD for Pherecon AM traps) for the use of Bt corn, plus the net benefit of Bt corn when using this optimal threshold. Table 1 reports the results of the economic analysis.

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Table 1. Optimal Bt corn treatment threshold (BTD) and net benefit for Bt corn.

	Corn price ($/bushel)			
	$2.00	$2.50	$3.00	$3.50
Optimal threshold (BTD) to indicate use of Bt corn	6.06	4.25	2.20	2.20
Net benefit of Bt corn ($/acre) when using threshold	$1.40	$3.12	$5.25	$7.46
Standard deviation ($/acre) of net benefit	$21.08	$30.73	$42.98	$50.40
Percent years use Bt corn when using threshold	23%	31%	42%	42%

In the analysis we assumed a mean yield of 150 bu/acre with a coefficient of variation of 30%, as well as a Bt corn technology fee of $19.20/acre. Higher average yield will decrease the threshold slightly and increase the net benefit. Under all corn prices the average net benefit of using Bt corn under the IPM practice is positive, but we find a tremendous amount of variation around this average. In our simulation growers who always treated their fields regardless of rootworm pressure experienced negative net returns on average from Bt corn, though they do decrease the risk of large negative losses. Finally, we note that, as with all such analyses, many factors are missing. For example, the benefit of reduced lodging is not included for Bt corn, as modeling lodging is difficult, since factors other than CRW are important contributors. Also, the control of other insect pests by Bt corn is not included.

The presentation will focus on the implications of these results, but it seems clear that for many Wisconsin farmers in the current climate of high corn prices, Bt corn should provide higher returns as well mitigate the risk of large yield losses. However, considering just the value of the root damage prevented by Bt corn, Bt corn will not be profitable in fields with low rootworm pressure. IPM scouting methods can be used to estimate rootworm pressure and to indicate when the cost of treatment is justified.

References

Burchett, A. 2001. Operation rootworm: Can biotechnology beat the billion dollar bug? Farm J. 125(11):16-18.

Cullen, E. 2005. 2005 Variant Western Corn Rootworm Survey. Wisconsin Crop Manager.

Cullen, E. 2005. Unpublished Field Data. Department of Entomology, University of Wisconsin-Madison, Madison, WI.

Mitchell, P.D., Grey, M.E. and Steffey, K.L. 2005. A Composed-Error Model for Estimating Pest-Damage Functions and the Impact of the Western Corn Rootworm Soybean variant in Illinois. Am. J. Agric. Econ. 68:332-344.

Wisconsin DATCP. 2006. Corn rootworm beetle survey. Wis. Pest Bull. 51(19):Nov. 3, 2006.

MULTIFLORA ROSE, A PLANT ON THE DECLINE IN WISCONSIN?

Mark J. Renz and Jerry D. Doll [1]

Introduction

Multiflora rose (*Rosa multiflora*), a nonnative shrub native to East Asia, has established throughout the Midwestern, Southern and Eastern United States. While this plant was intentionally introduced as an ornamental plant and for wildlife habitat, it has become one of the more common invasive plants in the eastern United States as it infests over 45 million acres (Underwood et al., 1996). Currently multiflora rose dominates pastures and edges of forests within the southern part of Wisconsin. Besides losses in productivity in pastures, multiflora rose greatly reduces the accessibility of these areas for recreation due to the creation of impenetrable thickets.

Recently a disease native to North America called rose rosette disease (RRD) has been found infesting multiflora rose plants within southwestern Wisconsin. This disease was first discovered in Canada in 1940 and currently it can be found in Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland Missouri, Nebraska, Oklahoma, Ohio, Pennsylvania Tennessee, Texas, West Virginia, and Wisconsin (Armine, 2002). Its distribution in Wisconsin is limited, but observations indicate that it is spreading. Currently infested multiflora rose plants have been seen in Vernon, Crawford, Grant, Richland, Sauk, Iowa, Lafayette, Green, Racine, and Dane counties (personal communication J.Doll, P. Pelliterri, A. Barta). This disease is fatal to multiflora rose as infected plants they die within 5 years (Epstein and Hill, 1999; Armine 2002). While no tests are currently available that verify if plants are infected, symptoms on multiflora rose are quite distinct making identification easy. Symptoms include a red coloration of the underside of leaf veins, elongated shoots, an increase in the number of thorns, and a proliferation of lateral buds on shoots that produce many reduced and malformed leaves (witches' broom).

RRD disease has not been isolated, but is believed to be a virus that is transmitted by an eriophyid mite (*Phyllocoptes fructiphylus*). This mite has been shown to be able to transmit the disease under greenhouse and field conditions (Armine, 2002). Dense multiflora rose stands in full sunlight appear to be more suitable for rapid spread of the disease, than sparse stands in shaded conditions. RRD also can infect some ornamental and native rose species/cultivars so caution should be used if considering trying to introduce this disease artificially.

Natural spread of RRD has been reported throughout the United States. In Iowa spread generally has not been explosive with the number of infected plants in a field generally remained the same or slowly increasing over time (Epstein and Hill, 1999). A few sites in Iowa were observed to have a rapid increase in infection rates over a 2 to 3 year period, but the rate rapidly decreased after infected plants died (Epstein and Hill, 1999). The method of spread is believed to be from the mite vector which can travel by wind and on bodies of small arthropods such as aphids and thrips. Lack of spread is believed to be due to several factors related to the vector's ability to reproduce, spread and over-winter. For example cold temperatures ($< -31^{o}C$) and rapid changes in daily temperature in the early winter ($17^{o}C$) have been observed to kill symptomatic shoots and the mite vector that over-winters on these shoots (Epstein and Hill, 1999; Armine, 2002). It has also been observed that when multiflora rose is drought stressed, infection rates from *P. fructiphylus* are dramatically reduced (Armine, 2002). Armine (2002) believes that *P.*

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fructiphylus require new vegetation that lacks a thick cuticle in order to transmit the disease (Armine, 2002). These factors are believed to limit the long-distance movement and often result in localized spread only. For example in Iowa, Epstein et al. (1997) found no mite vectors and no symptomatic plants within 150 to 300 meters from artificially inoculated source plants during a three year period. After three years, *P. fructiphylus* populations dramatically declined within the area. Associated with this drop in mite populations was a reduction in symptomatic multiflora rose plants within the immediate area with infected plants only seen within 20 meters of initial source plants 4 to 5 years after inoculation (Epstein et al., 1997). Some areas appear to support more rapid spread of RRD. In Maryland, one infected plant was discovered in 1997, but by 2000 numerous infected areas were found throughout five counties (Tipping and Sindermann, 2000).

Observations were initiated in 2004 to document the development of RRD on multiflora rose within a pasture in Wisconsin and to determine length of time for death of infected plants. The pasture is in Richland Center Wisconsin, and plants were selected on the edge of a newly observed RRD infected multiflora rose population. Twenty plants were selected that varied in size and all had minor to no symptoms present in 2004. Estimates of injury and mortality were assessed in June in 2005 and 2006. Analysis of variance was used to determine if bush size was related to health rating. Paired T-tests were used to assess the difference between 2005 and 2006 ratings.

Results and Discussion

Within the entire pasture, infection of multiflora rose plants increased from 2004-2006, with a visible decline of multiflora rose cover throughout the field (personal observation J. Doll). Multiflora rose health declined rapidly as health ratings were significantly higher (worse) ($P<0.0001$) in 2006 compared to 2005 (Figure 1). Once symptoms appeared, decline in the health occurred quickly as plants averaged a 3 point increase in injury rating from 2005-2006 with a

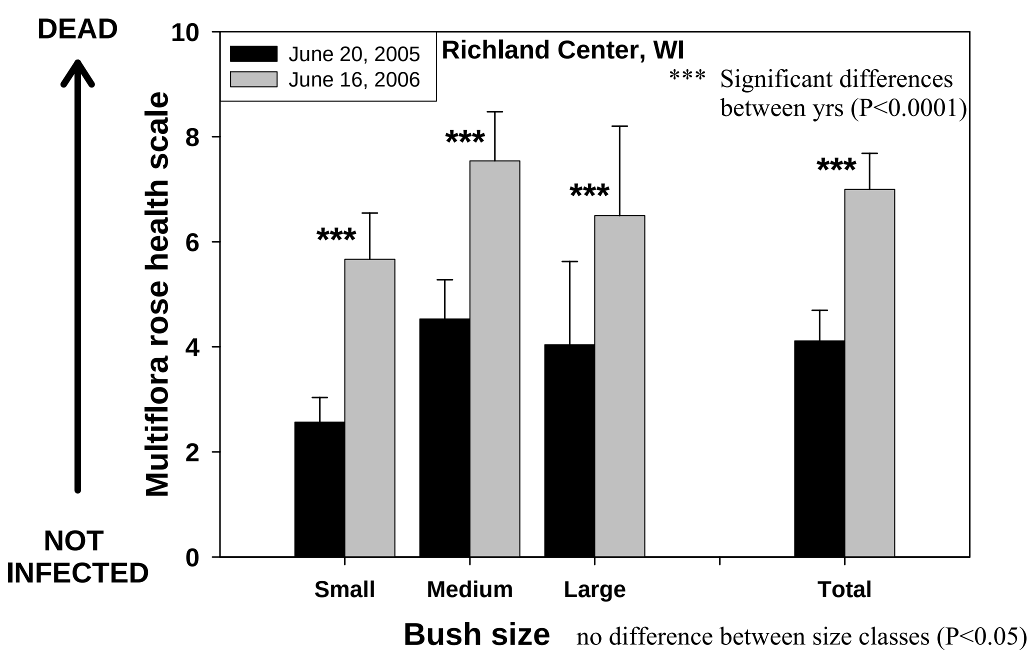

Figure 1. Average visual rating of multiflora rose health 1 and 2 years (2005-2006) after rose rosette disease symptoms appeared. 0 = Healthy plant; 10 = dead plant.

maximum of 6 (data not shown). Size classes of bushes did not influence injury ratings in either year. In 2006, mortality was observed in 5 out of the 20 multiflora rose plants (data not shown). It appears that size of plants may be important in the time to death as 4 out of the 5 plants that died were categorized as small. While short-term observations indicate that multiflora rose populations may be reduced by 90% or more by RRD, the long-term results are likely more complex. As large shrubs die, RRD frequency in the area dramatically decline, allowing seedling multiflora rose plants to establish (Armine, 2002). These seedlings can reestablish multiflora rose populations (Armine, 2002). Rose rosette disease remains present at the site, but infection rates remain low (20 to 25 %) until conditions that cause its spread reappear causing another large-scale reduction in multiflora rose populations (Armine, 2002). This cycling of infection and reestablishment is common with biological control programs, and additional management will be required to reduce multiflora rose populations further. Future research looks to integrate other management methods with RRD to attempt to achieve greater reduction in populations.

References

Armine, J.W. 2002. Multiflora rose. p. 265-292. In R. Van Driesche et al. (ed.) Biological control of invasive plants in the eastern United States. USDA Forest Service Pub. FHTET-2002-04.

Epstein, A.H., and J.H. Hill. 1999. Status of rose rosette disease as a biological control for multiflora rose. Plant Dis. 83(2):92-101.

Epstein, A.H., J.H. Hill, and W. Nutter. 1997. Augmentation of rose rosette disease for biocontrol of multiflora rose (*Rosa multiflora*). Weed Sci. 45:172-8.

Tipping, P.W., and A.B. Sindermann. 2000. Natural and augmented spread of rose rosette disease of multiflora rose in Maryland. Plant Dis. 84(12):1344.

Underwood, J.F., M.M. Loux, J.W. Armine, and W. B. Bryan. 1996. Multiflora rose control. Ohio State Univ., Ext. Bulletin no. 857. Columbus, OH.

ARE TWO-PASS HERBICIDE PROGRAMS VIABLE?

Chris Boerboom and Tim Trower[1]

Two-pass herbicide programs often refer to systems where a preemergence herbicide is applied near planting and is followed by a postemergence herbicide. In corn, the preemergence herbicide may target grass weeds or a mixture of grass and broadleaf weeds and the postemergence herbicide may be focused more on broadleaf weeds or perennial weeds. In soybean, it may be more beneficial to target broadleaf weeds with the preemergence herbicide because grass weeds are easily controlled postemergence with glyphosate. In general, the benefit of a two-pass program may be more frequent and of greater magnitude in corn than soybean, but two-pass programs in soybean still need to be considered.

Before asking if two-pass herbicide programs are viable, it's more important to consider why two-pass programs are even needed. Reasons why two-pass programs fit in corn and soybean weed management systems include (1) improving controlling of problem weeds; (2) reducing the risk of yield loss from late postemergence applications; and (3) increasing herbicide diversity to reduce the risks of herbicide resistant weeds.

Problematic Weeds

Wisconsin growers and agri-professionals are challenged to control several problematic weeds. The top five problematic weeds in soybean and corn were identified in 2005 by agri-professionals (Table 1). This list includes giant ragweed in both crops and waterhemp in soybean, which are weeds that are difficult to control for an entire season with a single herbicide application. Giant ragweed is a particular problem with postemergence programs because it grows so rapidly that it may become too large for effective control with postemergence herbicides or compete significantly with the crop before it is controlled. Unfortunately, highly effective preemergence herbicides are not available in corn or soybean to control giant ragweed. However, preemergence herbicides can suppress the giant ragweed so that postemergence herbicides are effective. Waterhemp differs from giant ragweed in that it creates more problems because of its mid and late season emergence and ALS herbicide resistance. This emergence pattern increases the value of postemergence herbicides when preemergence herbicides lose their residual activity.

Table 1. Most problematic weed species identified by agri-professionals in soybean and corn in 2005.

Species	Soybean	Species	Corn
C. lambsquarters	63%	Giant ragweed	19%
Giant ragweed	9%	Crabgrass spp.	15%
Ragweed spp.	4%	C. lambsquarters	14%
Dandelion	4%	Foxtail spp.	9%
Waterhemp	4%	Velvetleaf	7%

Common lambsquarters are also a major problem in Wisconsin. It is the main weed problem in soybean and in the top three weeds in corn according to agri-professionals (Table 1). Apart from some triazine resistant populations, common lambsquarters generally has been controlled successfully with preemergence or postemergence herbicides. However, lambsquarters control with glyphosate has been less consistent in recent years. Part of the reason for this

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problem may relate to the size of lambsquarters when they are sprayed. In a recent survey of agri-professionals, 69% of respondents commented that lambsquarters are sprayed when they are greater than 4 inches tall (Figure 1). It is likely that a preemergence broadleaf herbicide would reduce the size of these lambsquarters when they are sprayed postemergence with glyphosate.

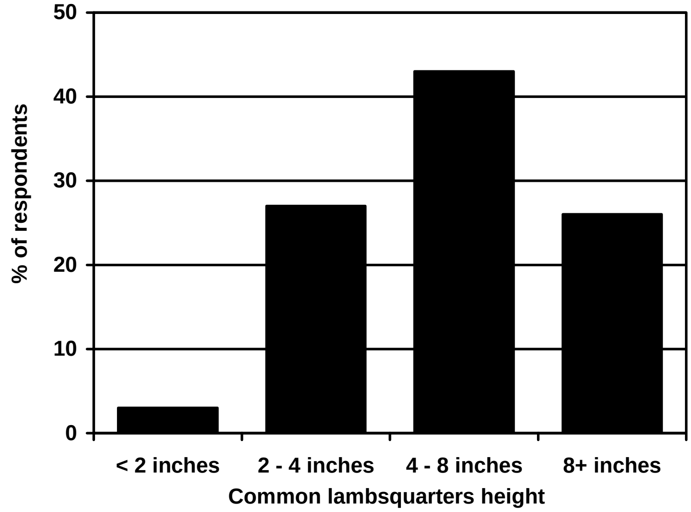

Figure 1. Height when lambsquarters are sprayed with glyphosate according to agri-professionals in Wisconsin (n = 302).

Early Season Weed Competition and Risk Management

While poor control of these weeds and their effect on yield is a problem, the economic effect of poorly timed weed management may be just as costly. Many research studies have demonstrated the effect of early season weed competition on crop yield. For example, we compared the effect of controlling weeds postemergence with glyphosate in corn when they reached a 4-inch height or at a 12-inch height as compared to being controlled preemergence in 2006. Although the 12-inch weed removal treatment had the least weed biomass in the fall, the average yield of the 12-inch removal treatment was 194 bu/a, which was 12 bu/a less than the 4-inch removal treatment and 15 bu/a less than the preemergence treatment (data not shown). We have also measured the value of preemergence herbicides in reducing the risk of yield loss from late applications of postemergence herbicides (Figure 2). In this 2-year study, half rates of common preemergence herbicides were applied alone or were followed with a standard glyphosate application. The half rate of these preemergence herbicides provided partial weed suppression, which substantially increased corn yield when followed with the postemergence glyphosate. The single application of glyphosate yielded 165 bu/a, whereas corn yielded 189 bu/a when averaged across the seven two-pass herbicide programs.

The effect of early season weed competition can be estimated easily with the WeedSOFT yield loss calculator located at http://weedsoft.unl.edu. Using a scenario with four common lambsquarters per ft^2 across a range of soybean growth stages, this web tool calculates potential yield losses as the lambsquarters are allowed to compete for increasing durations (Figure 3). With 8-inch tall lambsquarters and V4 soybean, slightly more than 3 bu/a might be lost from a 50 bu/a yield potential at a cost of $19/a. This represents the economic risk of a delayed herbicide application. Other scenarios in corn or soybean with single or multiple weeds can easily be simulated with this web tool.

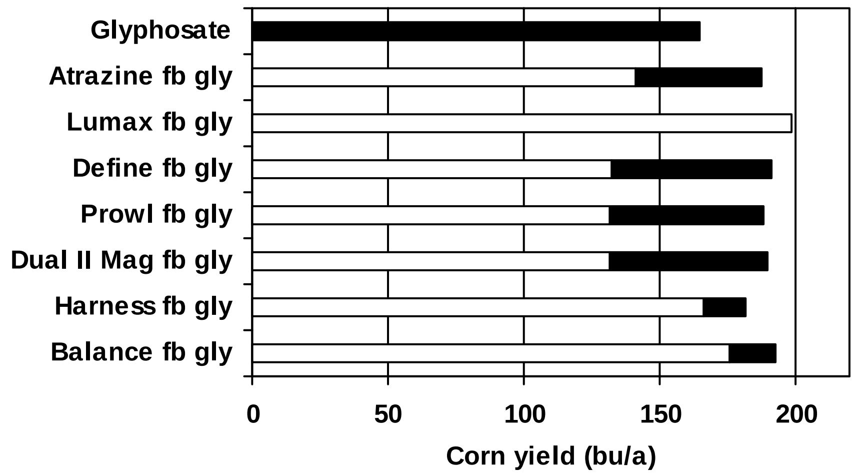

Figure 2. Average corn yield with half rates of preemergence herbicides alone (white bar) compared to the preemergence herbicide followed by (fb) glyphosate (white plus black bar). Experiments conducted at Arlington Ag Research Station in 2005 and 2006.

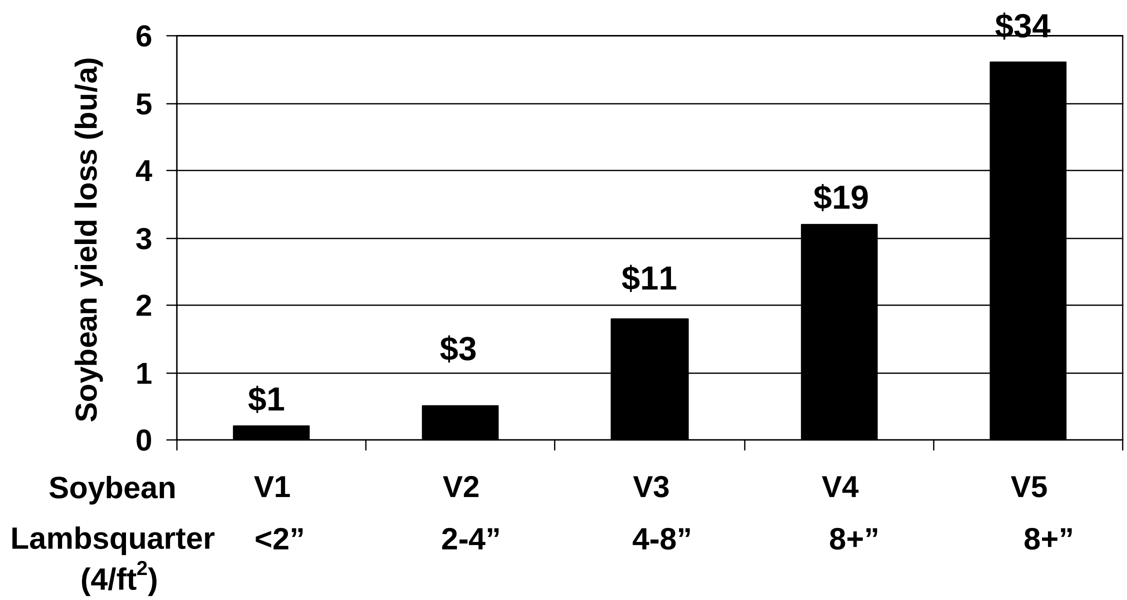

Figure 3. Estimated soybean yield and economic losses when common lambsquarters are controlled at increasing soybean growth stages and common lambsquarters heights.

Herbicide Resistance Management

Two pass herbicide programs may also contribute to herbicide resistance management strategies in addition to improving weed management or reducing risk. Of concern, the number of glyphosate-resistant weeds in the US is increasing (Figure 4) and includes several weeds that are common in Wisconsin (i.e., waterhemp, giant ragweed, horseweed, and common ragweed). Is there a reason for concern? Most agri-professionals (81%) reported that they believe glyphosate-resistant weeds will have some or frequent effects, especially with problem weeds in Wisconsin (data not shown). The contribution of two pass programs to resistance management can be to reduce the number of weeds that are treated with the same herbicide. Relative to glyphosate resistance, the use of a preemergence herbicide may control a majority of the weeds so that only a small number of remaining weeds are exposed to glyphosate This likely reduces the selection pressure for resistance for many weeds. However, it may not be as effective on weeds like giant ragweed that are only suppressed by preemergence herbicides or on weeds like waterhemp that can emerge after the residual activity of preemergence herbicides dissipates. Still, it is better than relying solely on postemergence applications of glyphosate.

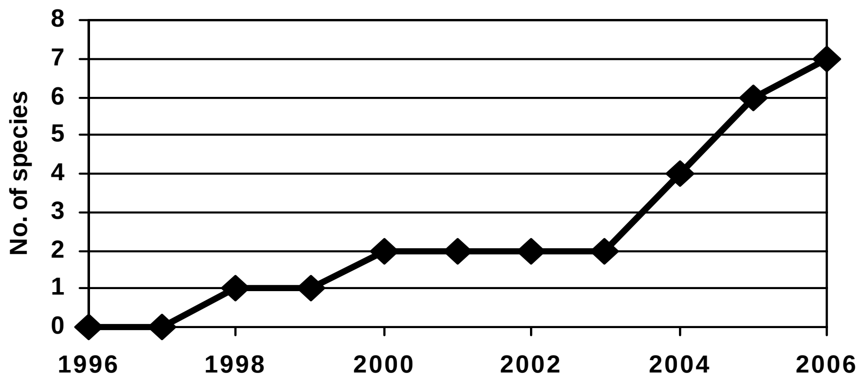

Figure 4. Number of glyphosate-resistant weed species reported in the United States since the introduction of glyphosate-resistant crops.

Conclusions

The focus of this paper is whether or not two-pass herbicide programs are viable. Three benefits of two-pass programs have been presented that include improved weed control, reduced economic risks, and increased herbicide diversity, which will reduce selection for herbicide resistance. However, two-pass herbicides programs may be more costly than single pass programs. A preemergence herbicide program has the cost of the herbicide(s) and the application. In a no-till system, the preemergence herbicide can be added to the burndown herbicide application so the added cost is only the cost of the herbicide. The cost of the preemergence herbicide may be low with herbicides like atrazine to more expensive premixtures. Many useful preemergence herbicides might cost $7 to 15/a and the cost-to-benefit ratio may be favorable in many situations, especially in corn. On farm tests are currently being conducted in soybean to determine the frequency of economic benefits with two-pass programs.

Are two-pass herbicide programs viable? The answer is yes. Are they always justified? It depends on the crop, the weed spectrum, the weather, the number of acres to be treated, and the resources available to spray the acres. These questions need to be assessed by farm managers to determine the right answers.

ATRAZINE PROHIBITION AREAS: ATRAZINE REUSE STUDY

Bruce D. Rheineck[1]

Background

Groundwater monitoring initiatives in the 1980s and 1990s in Wisconsin discovered that the herbicide atrazine and its chlorinated metabolites are present in a variety of wells and aquifers around the state. The atrazine in groundwater was believed to have resulted from the legal use of atrazine (non-point source) and from improper handling, storage and disposal (point source). The distribution of atrazine detections in the state is still widespread. The most recent random statewide survey conducted by the department in 2001 estimated that about 12% of the groundwater in the state contains atrazine or its chlorinated metabolites. And about 1% of the groundwater is over 3.0 µg/L, the health based Enforcement Standard (ES) for atrazine.

Regulatory authority for protection of groundwater from pesticides, including atrazine, falls under ch. 160, Stats., and ch. ATCP 31, Wis. Adm. Code. Both the statute and code, describe the measures DATCP must take in response to document groundwater contamination by pesticides. For groundwater contamination above the ES, the department must prohibit the activity or practice that caused or may affect the contamination.

The original atrazine rule, ch. Ag 30, Wis. Adm. Code (now Ch. ATCP 30, Wis. Adm. Code), was created in March 1991 to protect Wisconsin's groundwater. This rule restricted the use of atrazine on a statewide basis and established one atrazine management area (AMA) and six prohibition areas (PAs) in which the use of atrazine was further restricted or prohibited.

Additional amendments to the atrazine rule were promulgated in March 1993. These amendments included further limiting the use of atrazine in the entire state and the replacement of AMAs with PAs. Over the years as additional testing uncovered more drinking wells contaminated by the legal use of atrazine, additional PAs were created. Currently there are 102 PAs in the state covering over 1.2 million acres.

In 1998, the department responded to grower and industry input and implemented a rule change that allows the department to consider repealing or modifying PAs in areas where the groundwater contamination from atrazine has improved. The department must find all of the following conditions met before it considers whether or not to repeal or reduce the size of a prohibition area:

- Tests on at least three consecutive groundwater samples, drawn from each well site in the prohibition area at which the atrazine concentration previously attained or exceeded the groundwater enforcement standard, show that the atrazine concentration at that well site has fallen to and remains at not more than 50% of the enforcement standard. The three consecutive samples must be collected at each well site at intervals of at least 6 months, with the first sample being collected at least 6 months after the effective date of the prohibition. A monitoring well approved by the department may be substituted for any well site which is no longer available for testing.

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- Tests (if any) conducted at other well sites in the prohibition area, during the same retesting period, reveal no other atrazine concentrations that exceed 50% of the enforcement standard.

- The department determines, based on credible scientific evidence, that renewed use of atrazine in the prohibition area is not likely to cause a renewed violation of the enforcement standard.

To evaluate the first condition, the department tests all available wells in atrazine PAs that have ever exceeded the ES as part of a yearly survey called the Exceedance Survey. To help answer the third condition, the department designed and implemented a seven year study of renewed atrazine use impacts in existing PAs (Atrazine Reuse Study). Evaluation of the second condition will not be conducted until the department determines that conditions one and three have been met.

Exceedance Survey Results

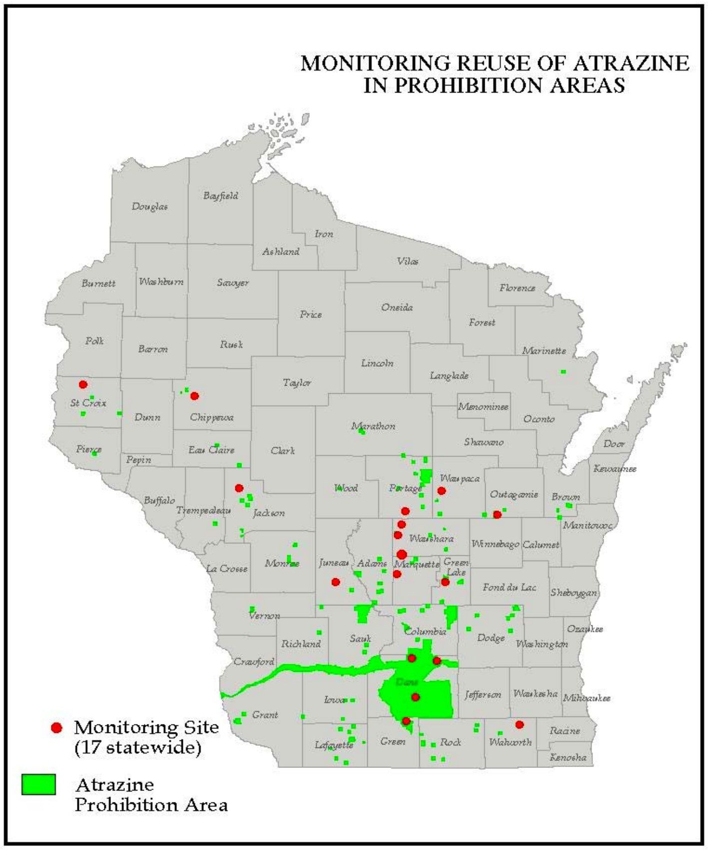
The Exceedance Survey began in 1995 and is a progam to sample water supply wells that have exceeded an ES for a pesticide. The survey started as a public service to well owners affected by pesticide contamination of their water and as a way to study the changes in pesticide concentrations over time. The survey includes both farm and non-farm wells supplying water for human consumption. Most of the wells in the survey are included due to an exceedance of the ES for atrazine.

Since the repeal process was established in ch. ATCP 30, Wis. Adm. Code, in 1998, the Exceedence Survey has also been used to determine if wells in PAs meet the first criteria for the repeal process. Currently we have data tracking 143 wells that have contained atrazine over the ES. Of these 143 wells, 94 show a downward trend, 17 are stable, and three show an increase. Ten of the 143 wells are still over the ES. An additional 29 wells do not have enough samples to determine their status. Applying the first condition of the repeal process to the results from these wells indicates that 21 PAs currently meet the first criteria.

It should be noted that the department is not currently able to track wells in all the atrazine PAs. Some well owners have chosen not to participate in this voluntary program, and twenty-five wells in PAs have been abandoned. In these PAs, gathering data on the first repeal criteria would require a substitute monitoring well be installed to mimic the original well.

Atrazine Reuse Study

The department's Atrazine Technical Advisory Committee provided extensive input on the design of the Atrazine Reuse Study. Syngenta, a manufacturer of atrazine, provided a portion of the funds and all of the laboratory analysis for the study. The department also confirmed the analysis by collecting split samples and analyzing the samples at the department's laboratory. The study recruited production growers with fields in older (1993 or 1994) PAs who were willing to grow corn, use atrazine and report pesticide use to the department. The selected fields were tested quarterly utilizing shallow monitoring wells for 5 to 7 years. The selected fields also needed to meet soil, topographic and geologic conditions to allow the study to be completed in a reasonable timeframe and cost. Seventeen growers with fields in PAs throughout the state (see figure 1) provided the study sites for the department.



The soil of the study fields were grouped into coarse and medium texture sites following the rule criteria in ch. ATCP 30, Wis. Adm. Code. The fields were screened to keep the slope under 5%. Study fields were selected such that the water table was in unconsolidated materials, avoiding areas where the water table was in bedrock. The unsaturated zone was of equal or greater permeability than the overlying soil. Depth to groundwater was less than 30 feet. The water table was not within the root zone of the crop being grown. The grower agreed to use atrazine on the monitored field (and was encouraged to use the highest legal use rate) at least three times during the study, depending on their crop rotation scenario. Products containing cyanazine or simazine were not allowed to be used during the study (since they form some of the same chlorinated residues as atrazine), although other pesticides and fertilizers were applied as needed. The grower selected the tillage and application method best suited for their operation.

Since the study fields were located in existing atrazine PAs, which by definition had at least one drinking water well over the ES at some time, the size of the area granted a research exemption to apply atrazine was limited to 10 to 40 acres. Three monitoring wells were installed in the middle of the atrazine treated area in the direction that the grower worked the field. Each well had a 5- or 10-foot screen with 3 to 4 feet of open interval below the water table. Wells were sampled following written sample collection procedures designed to minimize the possibility of cross contamination and following department chain-of-custody requirements to ensure adequate documentation of laboratory results.

Of the 17 sites in the study, one was excluded from the analysis, for not disclosing the presence of a septic drain field in the study field and for not following other study protocols. Of the remaining 16 sites, seven were unable to meet the requirement of applying atrazine at least three times during the course of the study. The reasons for this ranged from forgetting to include atrazine in the application, to changes in the planned crop rotation. These seven sites with only one or two applications of atrazine are broken out separately in the analysis presented below. Results of the three wells at all of the sites are shown in graphs in the appendix.

The table below summarizes some of the results by study site. Two conditions are evaluated in this table. First, did any of the three in-field wells at a site ever exceed the ES for atrazine, if so how often? Second, at the sites where all of the three wells started under the ES, how many times, if any, did one or more wells later go above the ES once renewed use of atrazine began?

Results by Site

9 sites with at least 3 applications of atrazine:

Condition	Result
One well over ES at least once at the site	9 of 9
All wells start below at the site, with 1 or more wells later over ES	4 of 4

7 sites with one or 2 applications of atrazine:

Criteria	Result
One well over ES at least once at the site	3 of 7
All wells start below at the site, with 1 or more wells later over ES	1 of 5

Some wells at some sites started out above the ES even before renewed use of atrazine began. This was in spite of the fact that the study fields had not had atrazine applications for at least five years before renewed use of atrazine was allowed. This is likely due to a couple of factors; the long half-life of atrazine in water and soil, or the use of either cyanazine or simazine compounds in the years prior to the study. Eight of the 16 study sites had documented use of cyanazine or simazine in the 3 years before the study began.

Another way to summarize the results is by each individual well instead of grouped by site. These results are presented in the table below. Again two conditions are evaluated in this table. First, how many wells that start below the ES later exceed the ES for atrazine? Second, for wells that start over the ES, how many increase by at least three µg/L (the amount of the ES) once renewed use of atrazine began? Results here are also broken out by soil texture.

Results by Well

9 sites with at least 3 applications of atrazine – 27 total wells:

Criteria	Result
Wells that start below ES and later over ES	9 of 16
Wells that start above ES and later increase by at least 3 µg/l	9 of 11
Wells in medium texture soil that start below ES and later over ES	6 of 11
Wells in coarse texture soil that start below ES and later over ES	3 of 5

7 sites with one or 2 applications of atrazine – 21 total wells:

Criteria	Result
Wells that start below ES and later over ES	5 of 19
Wells that start above ES and later increase by at least 3 μg/l	1 of 2
Wells in medium texture soil that start below ES and later over ES	3 of 5
Wells in coarse texture soil that start below ES and later over ES	2 of 14

Advisory Committee Comments

On March 29, 2006, the Atrazine Technical Advisory Committee reviewed the results of the Atrazine Reuse Study. Staff presented a review of the design and implementation of the study, as well as a detailed presentation of the results. Departmental legal staff presented a review of the conditions contained in s. ATCP 30.375, Wis. Adm. Code, regarding repeal of PAs as well as a brief history of Wisconsin's groundwater law and the responses required when an ES or preventive action limit (PAL) is attained or exceeded in groundwater.

After discussing the study results, the advisory committee members were polled as to whether or not the third condition, that credible scientific evidence shows that renewed use of atrazine in PAs is not likely to cause a renewed violation of the ES, has been satisfied. Eight of the eleven members present felt the data do not support a confidence in repealing any PAs. Most suggested that the department remain open to new data and studies evaluating the impact of atrazine on the environment. One member was unequivocal and two members felt that the Atrazine Reuse Study and other scientific data do support the repeal of PAs. They suggested moving forward to repeal PAs in a measured manner. The measured approach they suggested was to find a subset of the 21 PAs that meet the first condition for repeal and allow the use of atrazine for five years, while sampling the water supply wells in the PA during that period.

Departmental Recommendation

Based upon a review of the Atrazine Reuse Study and input from the Atrazine Technical Advisory Committee, the department does not recommend moving forward with the repeal process for any existing prohibition areas at this time.

PESTICIDE REGULATIONS

Patricia Kandziora [1/]

Updates on select pesticide regulations will be covered in an overview, including references and opportunities for input.

[1/] Wisconsin Department of Agriculture, Trade and Consumer Protection.

HERBICIDE SELECTION NEAR SENSITIVE VEGETATION

Jed Colquhoun[1]

While instances of herbicide injury on non-target vegetation are still rare, the risk for such injury has increased in recent years for several reasons. First, expansion and interspersing of residential areas into traditionally agricultural lands increases the chance of non-target exposure. Two acres of farmland are lost every minute of every day in the U.S. (American Farmland Trust 2006). In Wisconsin, about 18,000 agricultural acres per year were developed from 1992 to 1997, representing an increase in rate of 70% over the previous 5 years. Second, recent expansion of specialty and value-added crops in traditional field crop land increases the probability that sensitive vegetation is nearby. Vineyards, orchards, ornamental nurseries and organic farms tend to be particularly at risk from nearby herbicide applications. In organic farming, for example, the organic certification that adds value to the crop can be compromised by non-target sources of herbicide residue. Third, some newer herbicides cause very obvious symptomology on non-target plants, even at very low doses.

The Association of American Pesticide Control Officials (AAPCO) conducted a national survey of suspected pesticide drift cases in 2005 (AAPCO 2005). Nationally, agricultural crops were the intended target of 70% of confirmed drift cases, and lawns and landscapes were the most frequent recipient (43%) of drift. Fifty-three percent of cases involved commercial applicators for hire, and 22% involved certified private applicators. In Wisconsin, it is worth noting that more confirmed drift cases occurred from applications to non-agricultural land (51%) than agricultural crops (42%). The five most common active ingredients involved in drift cases in Wisconsin were 2,4-D, glyphosate, dicamba, atrazine and mesotrione.

Issues surrounding potential non-target herbicide damage to nearby sensitive vegetation can be somewhat mitigated by taking measures to reduce the risk for herbicide movement at or after application, and having the knowledge and ability to accurately assess crop injury. In general, the risk of herbicide movement can be reduced with the following strategies. Keep in mind, though, that all herbicides can drift in the wrong climatic conditions or in a poor application.

1. <u>Don't</u> spray when:
    a. The wind speed is excessive or the direction is toward sensitive sites. As a matter of fact, a light breeze away from the sensitive site may be the most appropriate timing for an application.
    b. Temperature and humidity favor herbicide volatilization (conversion of an herbicide to the gaseous form that can travel long distances). In general, high air temperature and low humidity favor volatilization.

    c. Air inversions exist. In an air inversion, cool air is trapped near ground level, with a layer of warmer air above it. The inverted air can carry pesticides near ground level to non-target sites, instead of allowing vertical dissipation. Air inversions often occur during calm, clear nights, when ground cooling occurs rapidly.
    d. Nearby sensitive vegetation is at a sensitive growth stage. Grapes, for example, are very sensitive to phenoxy herbicides from bud break to bloom.

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2. Consider pesticide application techniques and equipment
    a. Drift reduction nozzles and spray additives can reduce the risk for spray particle drift, but will not overcome applications during poor climatic conditions, such as on a windy day.
    b. Spraying at lower pressures will increase spray droplet size, thus creating heavier droplets that fall to the target site faster than small droplets that are prone to drift prior to deposition.

The ability to recognize and accurately diagnose potential herbicide damage on sensitive vegetation is very valuable in potential off-target movement cases. General symptomology for the five herbicides cited in the AAPCO drift survey are included below.

Herbicide type	Example active ingredients	General symptomology
Synthetic auxins	2,4-D, dicamba	Leaf cupping. Fern leaf appearance where the leaf vein continues to grow, but the interveinal tissue is stunted. Twisted stems and petioles. New growth is sometimes condensed with a bushy appearance. Can be confused with cold damage.
Photosynthetic inhibitors	atrazine	Yellowing between leaf veins, beginning at outer leaf margin and moving inward towards the center of the leaf.
Amino acid synthesis inhibitors	glyphosate	General yellowing of growing points. In low doses, can cause cupped and curled leaves that appear similar to phenoxy herbicide damage. Growth is sometimes condensed with multiple branching and numerous small leaves. In some sensitive perennial crops, fall uptake can injure spring growth.
Bleaching herbicides	mesotrione	Very distinctive whitening or "bleached" appearance, particularly on foliage.

References

American Farmland Trust. 2006. Farming on the edge report. Accessed online (December 7, 2006): http://www.farmland.org/resources/fote/default.asp.

Association of American Pesticide Control Officials. 2005. Pesticide drift survey. Accessed online (December 7, 2006): http://aapco.ceris.purdue.edu/htm/survey.htm.

WORKING WITH AGCHEM DEALERSHIPS ON MODIFIED RULES

Duane Klein and Charlene Khazae [1/]

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[1/] Wis. Department of Agriculture, Trade and Consumer Protection, Madison, WI.

NITROGEN, PHOSPHATE, POTASH: AN OUTLOOK FOR FERTILIZER IN 2007

Sebastian Braum [1/]

Fertilizer prices in the U.S. are driven by global and domestic factors. Growing demand for grain worldwide, both for human consumption and for animal feed, has led to the lowest level of grain stocks ever. This has forced grain prices higher, which in turn increased the demand for macronutrient fertilizers and especially nitrogen fertilizer. In addition to the traditional grain uses, biofuels made from commodity crops are further increasing demand for grains and therefore fertilizer. Most of this growth in agricultural production and fertilizer demand comes from developing countries, with Brazil, China, and India having the most impact. At the same time, nitrogen production in the U.S. has experienced a steep decline as a result of rapidly rising natural gas prices. Consequently, U.S. nitrogen plants have become swing producers, dependent on the domestic price of natural gas. A large proportion of nitrogen fertilizer is now imported.

Phosphate and potassium have also been experiencing growing worldwide demand as grain production in the U.S. and overall ag production in developing nations expands. Most production areas in the developing nations are deficient in P and K, requiring substantial increases from current P and K application rates to reach their full production potential.

The most likely scenario for fertilizer prices in the U.S. in 2007 is stabilization at current levels. Due to the potential for supply shortages, both nitrogen and potassium may however see further price increases.

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MANAGING THE LIABILITY OF GMO CROPS

Jim Shelton and Chris Boerboom [1/]

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[1/] Jim Shelton, Landmark; and Extension Weed Scientist, Dept. of Agronomy, Univ. of Wisconsin-Madison.

HOMELAND SECURITY AND THE AG-CHEM FACILITY

Robin Schmidt and Eric Nelson[1]

Why are we concerned about agroterrorism? Intelligence reports indicate that those wishing to do us harm are already aware that attacking the agriculture sector would result in economic, psychological and infrastructure disaster for this country.

So how can we protect ourselves from such an attack? We need to work together to establish public and private partnerships that include prevention, planning and response activities.

Secure your facilities so that they do not make convenient targets. Your facilities contain products that would be of interest to potential terrorists (domestic as well as foreign). There are several tools available to help you identify where there may be weaknesses in your system. Carver + Shock is one such tool that the FBI is using in assessing various agriculture vulnerabilities in their Strategic Partnership Program for Agroterrorism (SPPA) initiative. This partnership is hoping to have a "turbo-carver" available soon for individual use.

Make sure your facility has plans in place for responding to a security breach. Know your local emergency management director, your agriculture inspectors, and other government contacts who may be able to assist and/or respond to an emergency situation. Keep accurate inventories of your products and if you see unusual activities, report them to law enforcement officials.

The Wisconsin Department of Agriculture, Trade and Consumer Protection is involved in many planning activities as they relate to homeland security, ensuring that agency responses will be effective and efficient. To that end, we have written the agriculture chapter of the state emergency response plan (called ESF-11). We have also worked with the Office of Justice Assistance in identifying Wisconsin's food and agriculture system as one of the top four critical infrastructure needing protection in the state. We have also participated in and conducted numerous county and state exercises testing the effectiveness of our plans and our communications. These exercises are highly valuable in enhancing our response capabilities.

Understanding how agencies will respond to a terrorist event will help you recover your business should you ever be the target of such an incident. That is why it is important to understand the role of your local emergency managers as they work with state and federal officials. While agriculture officials may take the lead managing the technical aspect of a response, the FBI is the lead agency in investigating any terrorism-related event.

[1] Agency Liaison for Food and Agriculture Security; Toxic Response Coordinator, Wisconsin Department of Agriculture Trade and Consumer Protection.

HOW DATCP INVESTIGATES COMPLAINTS

Dave Fredrickson 1/

The Department of Agriculture, Trade and Consumer Protection is the State lead agency for enforcing state and federal laws related to pesticides. These include standards for the packaging, labeling, storage, use and disposal of pesticides and their containers. The Agricultural Resource Management Division is the Division assigned to these responsibilities. Besides pesticide regulation the Division is also responsible for enforcing the state's feed and fertilizer laws. The Division responds to and investigates over 200 complaints a year related to our programs. The largest area of complaints does relate to pesticide use.

Over the years, the number of complaints received has declined. The largest decline is in the area of alleged pesticide drift. When complaints are received, the Section of Investigation and Compliance within the Bureau of Agrichemicals Management is the group that responds to complaints. It is important to note that our historical violation rate is under 50%, which means that all complaint investigations are investigated in a neutral manner. The enforcement specialist investigating a complaint is a fact finder, trying to collect all relevant evidence to determine if a violation has occurred.

This presentation will outline the process used to receive, investigate, and determine if violations of law have occurred. The presentation also will outline the compliance responses that may be taken if a violation is documented.

1/ Director of Investigation and Compliance, Bureau of Agrichemicals Management, Wis. Department of Agriculture, Trade and Consumer Protection, Madison, WI.

Commodities, Conservation and the 2007 Farm Bill

Patrick Murphy
Wisconsin NRCS
State Resource Conservationist

Farm Bill History

- Farm Bill are typically authorized on a 5 year cycle. (1985,1990,1996,2002,2007)
- Farm Bills provide a comprehensive template for US agriculture policy including price support, export and conservation programs.
- 1985 Farm Bill was historic in that it required USDA program participants to demonstrate some degree of environmental performance to earn program eligibility (HEL/ Wetland Compliance)

Conservation in the Farm Bill

- Set Aside Programs
  - 1950's Soil Bank Program
  - 1970's Water Bank
  - 1985 Conservation Reserve Program (CRP)
    - 1990,1996 and 2002 refined the Conservation Reserve Program created in 1985
  - 1996 Wetland Reserve Program (WRP), Grassland Reserve Program (GRP)

Conservation in the Farm Bill

- Working Lands Programs
  - 1970's
    - Annual Conservation Program (ACP)
    - Rural Clean Water Program (RCWP)
  - 1996 Farm Bill
    - Environmental Quality Incentives Program (EQIP)
    - Wildlife Habitat Incentives Program (WHIP)
  - 2002 Farm Bill
    - Conservation Security Program

Influences on the 2007 Farm Bill

- US Federal Budget Status
  - 2002 Farm Bill was passed during a period of federal budget "surpluses"
  - 2007 Farm Bill will be negotiated with a growing federal budget deficits
- Environmental Regulations
  - 2002 Farm Bill provided unprecedented levels of funding to help agricultural producers comply with environmental regulations
  - 2007 Farm Bill will be implemented during a period of increasing pressure to implement the Clean Water Act, Safe Drinking Water Act and the Clean Air Act.

Influences on the 2007 Farm Bill

- Energy Bills
  - Ethanol/biodeisel production subsidies
  - Alternative energy sources (bio-gas, wind farms in rural areas, pyrolysis, gasification
- Trade Agreements
  - Green Box" subsidies (non-trade distorting)
  - "Red Box" direct subsidy payments not specifically linked to the cost of producing the crop.
- Livestock health and bio-security

Influences on the 2007 Farm Bill

- "Expect to be surprised"
- National/international events occurring during the Farm Bill negotiations can have a disproportionate effect on the outcome
- Non-traditional crop producers are organizing to demand broader coverage of Farm Bill programs beyond the traditional feed grain/commodity crops
- Future role of Conservation Compliance (HEL/wetland)
- Public payments linked to "environmental services"

Timeline for the 2007 Farm Bill

- Fall 2006 – legislators interested in Farm Bill release "DRAFT" bills floating ideas
- February 2007 House and Senate Ag Committees begin drafting Farm Bill
- Early summer 2007 committees hold hearings to gauge response to proposals
- Mid-late summer congress debates Farm Bill and "adjusts" DRAFT legislation

Timeline for the 2007 Farm Bill

- By September 30, 2007congress must:
  - Pass a new Farm Bill
  - Extend the current Farm Bill
  - Revert to the 194? Farm Bill by law
- Congressional leadership has indicated that passage of a Farm Bill in 2007 is a priority

Implementation Issues 2002 Farm Bill

- Technical Service Providers (TSP)
  - TSP concept created by the 1996 Farm Bill to help implement the conservation provisions
  - 2003 TechReg process expedited certification and client access to TSP's
  - FY04/05 WI NRCS emphasized TSP TA direct payments to USDA program participants for 590/595 and engineering practices

Implementation Issues 2002 Farm Bill

- Technical Service Providers – continued:
  - FY-06: WI NRCS relied on EQIP cost sharing payment to cover all costs for practice installation
    - Annual allocation of TSP funds
    - Increased workload necessary to make separate FA and TA payments
    - Shift to Flat Rate Payments in 2007
    - Recognition of overlap in existing TA/FA payments

Implementation Issues 2002 Farm Bill

- Conservation Security Program (CSP)
  - CSP meets the definition of a "non-trade distorting" program (Green Box)
  - Passed as an "entitlement" in the 2002 Farm Bill but funding has been capped
  - Acceptance into the program has become competitive due to limited funding
  - Maintaining program integrity during larger scale implementation will be challenging

Implementation Issues 2002 Farm Bill

- Environmental Quality Incentives Program
  - Mandated "flat rates" to simplify contracting
  - Further guidance to minimize the number of components per practice
  - Change from traditional X% cost share rate
  - Increasing demand for limited funds

Implementation Issues 2002 Farm Bill

- Conservation Reserve Program
- 2007 and 2008 a significant amount of acreage will be eligible for re-enrollment
  - More consistent enforcement of contract cover requirements
  - Implementation of "mid-management" practices to maintain the integrity of contract cover
  - Competing demands for land

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NUTRIENT MANAGEMENT FOR GRAZERS

Nick Schneider [1/]

Introduction

Many farmers are working to have nutrient management plans in place on their farms by 2008. Methods needed to be developed that could help unique enterprises, such as managed intensive grazing farms, credit manure deposited during gleaning. A MALWEG (Multi-Agency Land and Water Education Grant) was awarded to Clark County to help fund and train grazers to prepare nutrient management plans. Fertility trends and methods used will be presented.

Rules and Regulations

The Wis. Department of Natural Resources Chapter 151 on Runoff Management states under item .07 (2) regarding nutrient management that "This performance standard does not apply to industrial waste and byproducts regulated under ch. NR214, municipal sludge regulated under ch. NR 113 or manure directly deposited by pasturing or grazing animals on fields dedicated to pasturing or grazing." However, the Wisconsin NRCS 590 Nutrient Management standard has specific provisions pertaining to gleaning/pasturing.

X. Definitions: Gleaning / Pasturing (V.A.1.m) – An area of land where animals graze or otherwise seek feed in a manner that maintains the vegetative cover over all the area and where the vegetative cover is the primary food source for the animals. Livestock shall be managed to avoid the routine concentration of animals within the same are of the field. Manure deposited near a well by grazing of livestock does not require incorporation.

A.1.m. "Where gleaning/pasturing occurs, verify through computations that the nutrients deposited as manure with a field, do not exceed N and P requirements of this standard."
A.2.b.(1) "When frozen or snow-covered soils…do not apply nutrients within the SWQMA except for manure deposited through winter gleaning/pasturing of plant residue."

For farmers with the hope of qualifying for the Conservation Security Program (CSP), soil sampling and possibly a nutrient management plan will be needed for eligibility.

Fertility Trends on Grazing Farms in Clark County

A detailed sampling of 10 well-established managed intensive grazing farms in north-central Wisconsin revealed some relevant trends; 58% of samples collected fell into the "low" fertility description for potassium. On a positive note, grazing farms tend to have desirable soil phosphorous levels. The 2000 to 2004 state average for phosphorous

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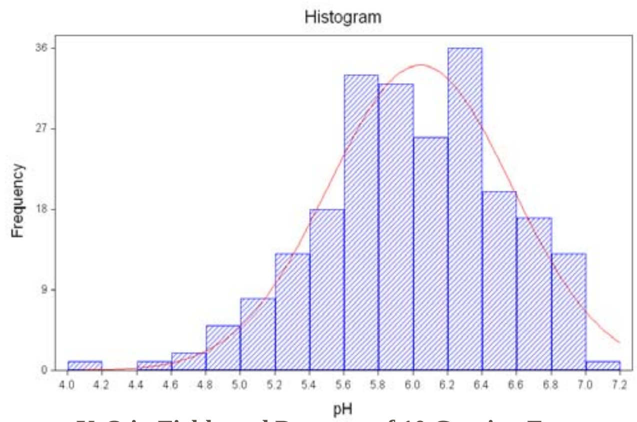
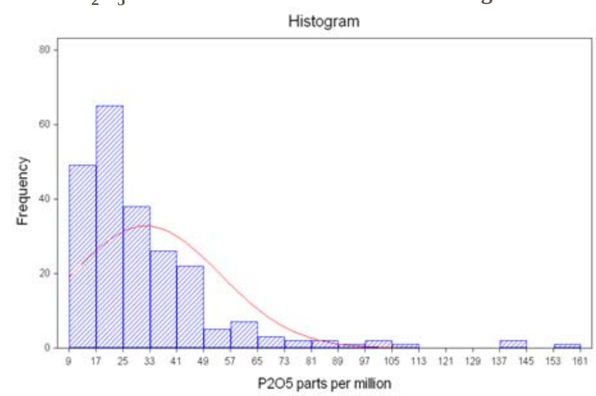
was 53 parts per million (ppm). Excessive phosphorus can contribute to degraded surface water quality. The group surveyed had an average of 32 ppm with 90% of samples under 50 ppm. While commercial fertilizer may or may not be needed across an entire farm, there likely will be paddocks that are high in fertility and others that are low in fertility on the same farm. These low fertility paddocks tend to have less forage productivity and may benefit from nutrient applications beyond the manure being deposited through gleaning. This can only be confirmed through adequate soil sampling.

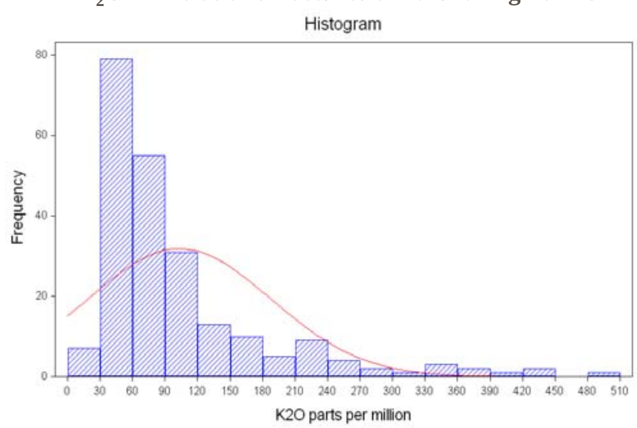
pH in Fields and Pastures of 10 Grazing Farms



P_2O_5 in Fields and Pastures of 10 Grazing Farms



K_2O in Fields and Pastures of 10 Grazing Farms



How to Collect Soil Samples on a Grazing Farm?

Invest some time in reviewing pasture design and then mark on a copy of field maps which samples will correlate to which paddocks. Depending on pasture design, it may be better to collect a soil sample every 2 to 3 acres rather than every five, especially if paddocks are small. There often is some discussion as to how deep soil samples should be collected in a pasture. At this point in time, the recommendation is to continue to sample to a depth of 6 to 7 inches for composite samples. Like in no-till, pastures may have problems with stratification where the nutrient content is greater closer to the soil surface. If nutrient stratification is a concern, collect cores from a 0- to 2-inch depth in one bucket and a 0- to 7-inch depth in another bucket, and then submit two samples.

How to Compute Nutrients Deposited as Manure and a Grazing Farm?

This depends on:

- Type of animal
- Size of animal
- Number of animals in the paddock
- Nutrient concentration in manure
- Length of time on the paddock
- Size of the paddock

A grazing manure deposit calculator has been developed to help compute the amount of nutrient being deposited in manure through livestock gleaning. The pounds of nutrient found through this method can be treated as a manure credit against the pasture nutrient needs. The calculator can be obtained by e-mailing nick.schneider@ces.uwex.edu. An upcoming release of SNAP-Plus is anticipated to contain a similar calculator.

Grazing Manure Deposit Calculator

Field / Paddock	Type of Animal	Weight (pounds)	Number of Animals		Manure (lbs/animal/ day)		Days on Paddock for season		Total Manure (lbs or tons)			Possible Adjustments* % manure on pasture		Manure on Pasture (tons)		Paddock Size (acres)		Manure per Acre (tons)		Test Manure or Standard Reference Value Nutrient Content (lbs/ton)				Grazing Manure** (lbs/ton)		
																				N	P2O5	K2O		N	P2O5	K2O
1	Jersey Cow	1000	40	×	85	×	5	=	17000	8.5	×	75%	=	6.4	÷	3	=	2.125	×	3	3	7	=	6	6	15
2	Steer	750	30	×	62	×	25	=	46500	23.3	×	85%	=	19.8	÷	10	=	1.97625	×	4	5	9	=	8	10	18
				×		×		=	0	0	×		=	0.0	÷		=	#DIV/0!	×				=	###	#####	#####
				×		×		=	0	0	×		=	0.0	÷		=	#DIV/0!	×				=	###	#####	#####
				×		×		=	0	0	×		=	0.0	÷		=	#DIV/0!	×				=	###	#####	#####

* 1. If paddock is more than 400 feet from water or milking facility, then all nutrients may be reduce by 15%.
Reduce by the percent of time livestock spend out of pasture, example- 4 hours/day in milking facility
**2. Transfer Grazing Manure Credit to Nutrient Balance Worksheet
Data must be entered in yellow collumns
Developed by: Nick Schneider, Clark County UWEX Crops and Soils Agent

Tips for successful nutrient management on grazing farms include:

- Reduce the number of deficient fertility paddocks.
- Avoid creating excessive fertility paddocks.
- Recognize distribution will not be perfect.
- Smaller, portable waters: Animals drink in smaller groups.
- Have dedicated areas for extreme heat.
- More, small paddocks result in a more even manure distribution.
- Credit grazed manure if at all possible.
- Apply a minimal amount of commercial fertilizer across the entire paddock if nutrients are needed.
- Apply commercial fertilizer to meet crop nutrient needs not met by deposited manure.

References

Wisconsin Department of Natural Resources (DNR). Chapter 151. Runoff Management.
Wisconsin Natural Resources Conservation Service (NRCS). Nutrient Management 590.

CREATING THE SCIENCE BASE FOR NUTRIENT MANAGEMNT GUIDELINES AND POLICY: SUCCESSES AND FUTURE NEEDS

Larry G. Bundy [1/]

Introduction

The goal of this paper is to review some of the soil fertility research projects I have contributed to and to make some comments about what results were successful and what areas have continuing research and education needs. In general, the purpose of much of this work was to create new knowledge and build upon existing information to provide a sound science base for nutrient management guidelines and recommendations for producers and the industry. In fact, many of the projects were initiated to answer questions or solve problems brought to our attention by farmers and the agricultural industry. The maintenance of a credible science base supporting nutrient management recommendations is made even more important when these recommendations are widely used as the basis for nutrient management regulatory policy.

Nitrogen Management

Nitrogen Rate Recommendations – Selecting the optimum N rate for a specific corn production situation is the most important N management decision for both agronomic and environmental reasons. Since 1982, more than 200 N rate response experiments with corn have been conducted under a wide range of soil, management, and climatic conditions in Wisconsin. Results from many of these experiments form the basis for our current corn N rate guidelines. Development of these guidelines emerged from work showing that optimum N rates for corn are a soil specific characteristic and are not well related to expected yield or yield goal (Vanotti and Bundy, 1994a;1994b). Recommendations introduced in 1989, were based on economically optimum N rates determined from corn N response experiments conducted on major soil groups used for corn production in the state. Recently, a regional approach to corn N rate guidelines was developed (Sawyer et al., 2006) in which corn N rate recommendations are calculated from N rate response experiments to maximize economic return to the N applied (MRTN). This MRTN approach has been incorporated into corn N rate guidelines for Wisconsin (Laboski et al., 2006), and 22 N response experiments were conducted throughout the state in 2006 to evaluate the MRTN rate guidelines and to further enhance the N response database.

Educational programs must continue to emphasize that yield expectations or yield goals are not a good predictor of corn N needs. This erroneous concept is apparently strongly engrained with corn producers. Future needs also include building the N response database through additional N rate response experiments conducted throughout the state to recognize the effects of changing production practices on corn N needs and to keep the database current. Historic data indicate that corn N use efficiency continues to increase, and this change should be reflected in future corn N rate guidelines.

Diagnostic Tests for Nitrogen – An essential component for accurate prediction of crop N needs is to account for the amounts of N supplied by the soil and other non-fertilizer N sources. Research in Wisconsin has shown that preplant soil nitrate testing (Bundy and Malone, 1988; Bundy and Andraski, 1995) and use of the presidedress soil nitrate test (PSNT) can be useful for

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improving N rate recommendations. Work based on historic data from the Lancaster Crop Rotation Experiment showed that nitrate carryover is likely in most years on medium-textured, well-drained soils in Wisconsin (Vanotti and Bundy, 1994c) and that the preplant soil nitrate test can be used to measure this N contribution. The sampling procedure for the preplant nitrate test was simplified based on work showing that the amounts of nitrate-N in the 2- to 3-ft soil depth could be reliably predicted using soil nitrate data from shallower soil depths (Ehrhardt and Bundy, 1995). The PSNT developed in Vermont and Iowa was calibrated for Wisconsin conditions and shown to be a reliable predictor of available N contributions from organic sources such as manure and previous legume crops (Bundy and Andraski, 1995; Andraski and Bundy, 2002). The more recent work (Andraski and Bundy, 2002) also identified the temperature dependency of the PSNT and that organic N credits were likely to be underestimated if early spring temperatures were more that $1^{o}F$ below the long-term average normal temperature. Work with the end-of-season corn stalk nitrate test confirmed critical values from Iowa research and showed that the test can identify sites with deficient, adequate, or excessive N supplies during the growing season (Bundy and Andraski, 1993).

Many attempts have been made to develop a diagnostic test for soil N availability, but none have proven satisfactory. The important influence of soil N supplying capability on estimating corn N needs is illustrated by a recent compilation of data on corn yield response to N fertilization from over 300 experiments in Illinois, Iowa, Minnesota, and Wisconsin showing that 50 to 70% of the observed corn yield was produced with N supplied by the soil alone (Sawyer et al., 2006). Wisconsin research to evaluate various tests for predicting soil N availability has yielded inconsistent results (Vanotti et al., 1995; Schoessow et al., 1996). Recently, a test based on soil amino sugar-N content (Illinois soil nitrogen test) received substantial publicity for its ability to predict soil N supplying capability. However, when this test was evaluated in Wisconsin and other states in the North Central Region, it was found to be ineffective in predicting soil N mineralization or corn N fertilizer needs (Osterhaus and Bundy, 2005; Osterhaus et al., 200_).

Possibly the greatest future need in this area is to continue work to develop a reliable procedure for predicting soil N mineralization on a site-specific basis. Since one-dimensional tests or procedures addressing this topic have not been successful in the past, the greatest benefits are likely to come from integrating information from several procedures to yield comprehensive information about soil N availability. This could include greater use of soil nitrate tests, which are currently under-utilized, accumulation of aerobic soil N mineralization data on a field-by-field basis, and use of an applied modeling approach that attempts to integrate some of the factors contributing to soil N supplying capability.

Corn N Response in Soybean-Corn Systems – Wisconsin's soybean acreage has increased dramatically in the last 20 years making prediction of corn N needs following soybean a critical question. Early work (Bundy et al., 1993) showed that N needs of corn following soybean were lower than those for corn following corn on medium-textured soils but that no adjustment in N rates was needed on sands and loamy sand soils. Further work (Vanotti and Bundy, 1995) indicated that a major component of the soybean effect on corn N needs was an increase in mineralization of the readily available N fraction of stable soil organic matter. Shoessow et al. (1996; 1998) found that tillage and residue management variables had little effect on N availability to corn following soybean. Collectively, these studies provided an adequate soybean-corn N response database to allow development of separate MRTN rate guidelines for this cropping system (Laboski et al., 2006). Future needs include monitoring of soil organic matter and N availability in long-term corn soybean cropping systems to measure potential declines in soil productivity due to enhanced organic matter decomposition in this cropping system. As was noted above for all cropping systems that include corn, additional N rate response experiments in soybean-corn systems are needed to enhance the N response database and to reflect the influence of changing production practices on corn N needs.

Tillage and Fertilizer Source Effects on Nitrogen Efficiency – Cropping systems with large amounts of corn residue (over 50% cover) often have increased N needs. Research in these systems showed that the increase in N requirement was largely due lower soil temperatures in high-residue systems that reduced the amount of N mineralized from organic matter during the growing season (Bundy and Andraski, 1997). Artificial cover providing the same coverage as corn residue had similar effects on N availability. In no-till corn systems, N applications to the residue in fall did not influence the rate of residue decomposition or N availability to subsequent crops (Bundy, 2001).

Ammonia volatilization losses from surface-applied urea can be a key factor affecting N use efficiency. In Wisconsin, maximum losses from urea-containing fertilizers applied to corn or grass pastures range from 20 to 25% of the applied N (Oberle and Bundy, 1987; Bundy and Oberle, 1988). Typical losses are usually substantially less than this due to climatic effects that influence these losses. However, these losses are often large enough to influence yields. For example, surface applications of 28% N solution were less effective than ammonium sulfate in no-till corn systems in two of three years (Bundy, 2001).

Nitrate leaching losses can also have major effects on N efficiency and potential losses of nitrate to groundwater, especially on coarse-textured soils. Timing of N applications (sidedress and split applications) and use of nitrification inhibitors with ammonium N sources can help control these losses. Polymer-coated urea materials can also reduce leaching losses especially where N is applied early in the growing season. Future needs include continued development and evaluation of fertilizers, fertilizer amendments, and application techniques to control ammonia loss from urea-containing fertilizers. It will also be increasingly important to recognize tillage and residue combinations that may affect N availability and use effective N application strategies to avoid N deficiencies.

Nitrogen Management for Winter Wheat – Studies to determine optimum N rates for wheat and to evaluate diagnostic tests to predict wheat N needs were conducted at 21 site-years (Bundy and Andraski, 2004). Results helped to establish current wheat N rate recommendations and showed that excess N fertilization lowered yields and economic return. The preplant soil nitrate test (conducted in August or September) was the best predictor of wheat N needs, and results supported the idea that winter wheat accumulates a substantial portion of its N requirement before dormancy. Future needs include expanding the wheat N response database to allow extension of the MRTN approach to N rate guidelines to include wheat. Additional work is necessary to identify optimum timing and N source effects on wheat N response including use of urease inhibitors and polymer-coated urea. Research is also needed to identify the mechanisms responsible for the decline in wheat yields with excess N.

Long-term Nitrogen Response Experiments – The value of long-term experiments is that they can often provide answers to current questions that were not being asked when the experiments were started years earlier. For example, the long-term continuous corn experiment at Arlington (established in 1958) and the Lancaster crop rotation experiment (established in 1967) have provided research environments for studies on long-term effects of N fertilization on soil N availability (Motavalli et al., 1992; Vanotti and Bundy, 1996; Vanotti et al., 1997), nitrogen carryover potential (Vanotti and Bundy, 1994c), long-term N use effects on soil productivity (Bundy et al., 2000), soybean N contributions to subsequent crops (Vanotti and Bundy, 1995), and N credits from legumes grown in crop rotations. Numerous studies in disciplines other than soil science have also utilized these experimental sites. An obvious need is to secure adequate permanent funding to maintain these long-term studies for use in future research.

Environmental Impacts of Nitrogen Management – Although it is well known that N management variables can influence the potential for N losses from cropland, few studies have actually measured N losses occurring under different N management regimes. Research with several cropping systems and N application rates in corn production showed that soil water nitrate-N concentrations at the bottom of the corn root zone increased as the amount of N applied in excess of the observed optimum N rate increased (Andraski et al., 2000). Results indicated that the amount of excess N applied and not the total N rate was the major factor controlling nitrate N losses. Subsequent work using isotopically labeled N fertilizer for sweet corn and potato on sandy irrigated soils showed that whole plant N recovery at recommended N application rates averaged 54 and 34% for sweet corn and potato, respectively (Bundy and Andraski, 2005). Very little fertilizer N was recovered by a winter rye cover crop or by a subsequent corn crop indicating that fertilizer N not recovered by the crop during the growing season is likely lost by leaching on these soils.

Corn Response to Starter Fertilizer

Use of starter fertilizer in corn production is a widespread and often profitable practice in Wisconsin. With increasing state-wide average soil test P levels and growing concerns about excess soil P contributing to P losses in runoff, the importance of starter fertilizer use needed evaluation. An initial examination of tillage, planting date, and starter fertilizer composition showed that the largest responses to starter fertilizer occurred in no-till systems with late planting dates (Bundy and Widen, 1992). This work also showed that the most consistent responses were obtained when starter fertilizers contained all three major nutrients (N, P, and K). Later work at 100 on-farm sites throughout the state showed that 40% of these sites gave a profitable response to side-placed starter fertilizer containing N, P and K, although most had excessively high soil test P and K levels (Bundy and Andraski, 1999). The major factors affecting starter response were planting date, hybrid relative maturity, and soil test K. The probability of response to starter on high-testing soils can be predicted based on planting date and hybrid relative maturity with the more frequent responses occurring at late planting dates with long-season hybrids (higher relative maturity). The starter fertilizer response with late planting dates and long-season hybrids is probably due to stimulation of early season corn growth rates by the starter fertilizer resulting in a realization of more of the crop's yield potential by the end of the growing season.

Implications and future needs emerging from this work include the following. The trend away from starter fertilizer use due in part to larger planters and time considerations probably means that growers are giving up yield increases that could be provided by starter fertilizer. The response to a side-placed N-P-K starter fertilizer usually cannot be obtained with other fertilizer application methods including broadcast treatments and use of low rates of fertilizer placed with the seed. Trends toward low rate starter applications that contain little or no K probably contribute to a growing problem with K deficiency. Potassium fertilizer use in Wisconsin has decreased substantially in recent years, and this trend needs to be reversed if major problems with K deficiency are to be avoided. Research needs include development of starter fertilizer application technologies that are compatible with large planters and minimize time requirements.

Management Practice Effects on Phosphorus Losses in Runoff

In 1998, a research effort was initiated to provide the research base to support phosphorus-based nutrient management planning in Wisconsin. These studies established the interactive effects of variables including soil test P, tillage, and manure applications on the relative risk of P losses in runoff from cropland (Bundy et al., 2001; Andraski and Bundy, 2003; Andraski et al., 2003). Additional work showed that excessive P levels in dairy diets resulted in higher manure P concentrations and substantially higher P losses in runoff when these manures were land applied (Ebeling et al., 2002). Roberson et al. (2007) showed that P losses from plant residues, such as alfalfa, could contribute to P in runoff from cropland, particularly after freezing or drying of the plant materials, but that these losses were strongly influenced by climatic variables.

Results from these and other studies were used to construct the Wisconsin P index, which is a semi-quantitative model for predicting the risk of runoff P losses on a field specific basis http://wpindex.soils.wisc.edu/. The P index is one of the options for P-based nutrient management planning included in the NRCS Nutrient Management Standard (590) which contains the requirements for nutrient management planning in the state. The effectiveness of the P index in identifying the risk of P losses in runoff was evaluated by comparing P-index values with field-scale annual P loss measurements. Results showed that the P-index was very effective in predicting the P losses that were observed in the field (Good and Bundy, 2005; 2006). To facilitate use of the P index in nutrient management planning, the index was incorporated into the SNAP-Plus nutrient management software program http://www.snapplus.net. This program calculates field-by-field P index values and provides nutrient application guidelines according to University of Wisconsin recommendations and the NRCS 590 nutrient management standard. It also provides a RUSLE2-based soil loss assessment that will allow producers to determine whether fields which receive fertilizer or manure applications meet tolerable soil loss (T) requirements.

Since much of the data base used to construct the P-index was obtained in small plot research, the effect of scale of measurement on observed P losses was compared at the plot and sub-watershed scale (Bohl et al., 2006). Results showed that P concentrations in runoff were usually similar between the two scales of measurement, thus confirming the validity of using small plot research data to develop P loss risk assessment tools like the P-index.

Future research needs include continued expansion of the P-index to include additional cropping systems and management scenarios. Since P loss risk is highly climate sensitive, further validation studies comparing predicted and observed P runoff losses under various climatic conditions are needed. The SNAP–Plus nutrient management planning software requires frequent updating to incorporate emerging research results.

References

Andraski, T.W., and L.G. Bundy. 2002. Using the PSNT and organic N crediting to improve corn nitrogen recommendations. Agron. J. 94:1411-1418.

Andraski, T.W., and L.G. Bundy. 2003. Relationships between phosphorus levels in soil and in runoff from corn production systems. J. Environ. Qual. 32:310-316.

Andraski, T.W., L.G. Bundy, and K.R. Brye. 2000. Crop management and corn nitrogen rate effects on nitrate leaching. J. Environ. Qual. 29:1095-1103.

Andraski, T.W., L.G. Bundy, and K.C. Kilian. 2003. Manure history and long-term tillage effects on phosphorus losses in runoff. J. Environ. Qual. 32:1782-1789.

Bohl, N.L., L.G. Bundy, C.A. Baxter, T.W. Andraski, and L.W. Good. 2006. Scale of measurement effects on phosphorus in runoff from cropland. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 45:288-295.

Bundy, L.G. 2001. Nitrogen applications and residue decomposition. New Horizons in Soil Science, no. 3-2001. Dept of Soil Sci., Univ. of Wisconsin-Madison. http://www.soils.wisc.edu/extension/publications/horizons/2001/Napp_residuedecomposition.pdf

Bundy, L.G., and T.W. Andraski. 1993. Soil and plant nitrogen availability tests for corn following alfalfa. J. Prod. Agric. 6:200-206.

Bundy, L.G., and T.W. Andraski. 1995. Soil yield potential effects on performance of soil nitrate tests. J. Prod. Agric. 8:561-568.

Bundy, L.G., and T.W. Andraski. 1997. Crop residue and nitrogen source effects on nitrogen availability in no-till corn. Proc. Wis. Fert., Aglime and Pest Mgmt. Conf. 36:216-225.

Bundy, L.G., and T.W. Andraski. 1999. Site-specific factors affecting corn response to starter fertilizer. J. Prod. Agric. 12:664-670.

Bundy, L.G., and T.W. Andraski. 2004. Diagnostic tests for site-specific nitrogen recommendations for winter wheat. Agron. J. 96:608-614.

Bundy, L.G., and T.W. Andraski. 2005. Recovery of fertilizer nitrogen in crop residues and cover crops on an irrigated sandy soil. Soil Sci. Soc. Am. J. 69:640-648.

Bundy, L.G., T.W. Andraski, and J.M. Powell. 2001. Management practice effects on phosphorus losses in runoff in corn production systems. J. Environ. Qual. 30:1822-1828.

Bundy, L.G., T.W. Andraski, and R.P. Wolkowski. 1993. Nitrogen credits in soybean-corn crop sequences on three soils. Agron. J. 85:1061-1067.

Bundy, L.G., and E.S. Malone. 1988. Effect of residual profile nitrate on corn response to applied nitrogen. Soil Sci. Soc. Am. J. 52:1377-1383.

Bundy, L.G., and S.L. Oberle. 1988. Evaluation of methods for control of ammonia volatilization from surface-applied urea-containing fertilizers. J. Fert. Issues. 5:24-30.

Bundy, L.G., M.C. Pellitteri, and P. Barak. 2000. Effects of nitrogen fertilizer use on soil characteristics and productivity. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 39:77-89.

Bundy, L.G., and P.C. Widen. 1992. Corn response to starter fertilizer: Planting date and tillage effects. Better Crops 76 (Winter):20-23.

Ebeling, A.M., L.G. Bundy, T.W. Andraski, and J.M. Powell. 2002. Dairy diet phosphorus effects on phosphorus losses in runoff from land-applied manure. Soil Sci. Soc. Am. J. 66:284-291.

Ehrhardt, P.D., and L.G. Bundy. 1995. Predicting nitrate- nitrogen in the two- to three-foot depth from nitrate measurements on shallower samples. J. Prod. Agric. 8:429-432.

Good, L.W., and L.G. Bundy. 2005. Validating the Wisconsin P index with measured runoff P losses from agricultural fields. In Proc. North Central Extension–Industry Soil Fert. Conf., Des Moines, IA. 21:115-122, Potash and Phosphate Inst., Brookings, SD.

Good, L.W., and L.G. Bundy. 2006. Development and validation of the Wisconsin phosphorus index. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 45:135-138.

Laboski, C.A.M., J.B. Peters, and L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. UWEX Publ. A2809. Univ. of Wisconsin-Extension, Madison, WI.

Motavalli, P.P., L.G. Bundy, T.W. Andraski, and A.E. Peterson. 1992. Residual effects of long-term N fertilization on N availability to corn. J. Prod. Agric. 5: 363-368.

Oberle, S.L., and L.G. Bundy. 1987. Ammonia volatilization from surface applied N fertilizers: Effects on corn and grass pasture yields and N uptake. Biol. Fert. Soils. 4:185-192.

Osterhaus, J.T., and L.G. Bundy. 2005. Determining economic optimum nitrogen rates with the Illinois soil nitrogen test and soil organic nitrogen fractions. In Proc. North Central Extension–Industry Soil Fert. Conf., Des Moines, IA. Vol. 21:123-129, Potash and Phosphate Inst., Brookings, SD.

Osterhaus, J.T., L.G. Bundy, and T.W. Andraski. 200_. Evaluation of the Illinois soil nitrogen test and soil organic nitrogen fractions for predicting corn nitrogen needs. Soil Sci. Soc. Am. J. 00:000-000. (In review).

Roberson, T., L.G. Bundy, and T.W. Andraski. 2007. Freezing and drying effects on potential plant contributions to phosphorus in runoff. J. Environ. Qual. 00:000-000. (Accepted 8/30/06).

Sawyer, J., E. Nafziger, G. Randall, L. Bundy, G. Rehm, and B. Joern. 2006. Concepts and rationale for regional nitrogen rate guidelines for corn. Publ. PM2015, Iowa State Univ. Extension, Ames, IA.

Schoessow, K.A., L.G. Bundy, and K.C. Kilian. 1998. Predicting optimum N rates for corn in soybean/corn rotations. Proc. Wis. Fert., Aglime and Pest Mgmt. Conf. 37:235-243.

Schoessow, K.A., K.C. Kilian, and L.G. Bundy. 1996. Site-specific prediction of soybean nitrogen contributions. In Proc. 26th North Central Extension-Industry Soil Fert. Workshop, St. Louis, MO, 20-21 November 1996. 12:27-40.

Vanotti, M.B., and L.G. Bundy. 1994a. An alternative rationale for corn N fertilizer recommendations. J. Prod. Agric. 7:243- 249.

Vanotti, M.B., and L.G. Bundy. 1994b. Corn nitrogen recommendations based on yield response data. J. Prod. Agric. 7:249- 256.

Vanotti, M.B., and L.G. Bundy. 1994c. Frequency of N fertilizer carryover in the Humid Midwest. Agron. J. 86:881-886.

Vanotti, M.B., and L.G. Bundy. 1995. Soybean effects on soil nitrogen availability in crop rotations. Agron. J. 87:676-680.

Vanotti, M.B., and L.G. Bundy. 1996. Soil organic matter dynamics in the North American Corn Belt: The Arlington Plots. p. 409-418. *In* D.S. Powlson et al. (ed.) Evaluation of soil organic matter models using existing, long-term data sets. NATO ASI Series, Vol. 138, Springer-Verlag, Berlin.

Vanotti, M.B., L.G. Bundy, and A.E. Peterson. 1997. Nitrogen fertilizer and legume-cereal rotation effects on soil productivity and organic matter dynamics in Wisconsin. p. 105-119. *In* E.A. Paul et al. (ed.) Soil organic matter in temperate agroecosystems: Long-term experiments in North America. CRC Press, Inc., Boca Raton, FL.

Vanotti, M.B., S.A. Leclerc, and L.G. Bundy. 1995. Short-term effects of nitrogen fertilization on soil organic nitrogen availability. Soil Sci. Soc. Am. J. 59:1350-1359.

NUTRIENT MANAGEMENT REGULATORY UPDATE

Jim Vanden Brook [1/]

FREQUENTLY ASKED QUESTIONS ABOUT DATCP'S NUTRIENT MANAGEMENT RULE

When will DATCP make changes to its nutrient management rules (ATCP 50 Wis. Admin. Code)?

We plan to present the final draft of the ATCP 50 Wisconsin Administrative Code to the Department of Agriculture, Trade and Consumer Protection (DATCP) Board in January 2007. If the Board approves the rule, it will go to the legislature where they may hold hearings and suggest changes back to DATCP before final promulgation.

When is a nutrient management plan required?

Under existing DNR and DATCP rules, all farmers who mechanically apply manure or commercial fertilizer to cropland (not just livestock operators) must have a nutrient management plan. Nutrients include nitrogen, phosphorus, and potassium from manure, legumes, organic byproducts, and commercial fertilizer. Nutrient applications follow soil test recommendations minus credits from nutrient sources. <u>State law makes enforcement contingent on an offer of cost sharing only for item 1. below.</u> A nutrient management plan is required when:

1. <u>A producer voluntarily accepts, or is offered, government cost-share dollars for nutrient management or the installation of manure storage.</u>
2. A producer voluntarily continues participation in the farmland preservation program (FPP).
3. A producer is regulated under a county manure storage or livestock siting ordinance.
4. A producer is regulated under a DNR Wisconsin pollution discharge elimination system permit (WPDES).

Where Wisconsin law makes enforcement contingent on an offer of cost sharing, local governments can make an offer of cost share and require nutrient management. Nutrient management planning enforcement can take effect everywhere in Wisconsin after January 1, 2008. However, nutrient management planning enforcement is limited by the availability of cost-share funds and governmental regulation at the state and local levels. The cost-share offer must cover at least 70% of the farmer's annual cost to implement nutrient management (90% if there is an economic hardship). The farmer may accept an alternative flat payment of $7 per acre per year for a four year period. Additional cost sharing is not required by a local government for farmers to continue this practice.

Who can write and approve a nutrient management plan?

A qualified nutrient management planner must prepare or approve each nutrient management plan. Persons holding one of the following are presumptively qualified:

1. Certified as crop consultant by the National Alliance of Independent Crop Consultants (NAICC)
2. Certified as crop advisor (CCA) by the American Society of Agronomy, Wisconsin Certified Crop Advisor Board
3. Certified as a professional agronomist (CPAg) by the American Society of Agronomy
4. Certified as a soil scientist by the Soil Science Society of America
5. A farmer is presumptively qualified to prepare their own nutrient management plan if the farmer has completed a DATCP-approved training course and the instructor approves the first

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annual plan within the preceding 4 years. Except in the case of local livestock siting ordinances, where this qualification does not apply.

Which version of A2809, NRCS 590 nutrient management standard, and Conservation Planning Technical Note will be included in ATCP 50?

ATCP 50 will require nutrient management plans to be based on UWEX Publ. *Soil Test Recommendations for Field, Vegetable and Fruit Crops, A2809 (1998)* or most current version if preferred by the landowner. ATCP 50 will also require nutrient management plans to be based on September 2005 NRCS 590 nutrient management standard. The Conservation Planning Technical Note is being updated to include these changes before rule promulgation.

1. Add nutrient management planning for cranberries.
2. Delete Logan Labs of Ohio from the list of DATCP certified soil testing laboratories.
3. Update the list of soils with high potential for nitrate leaching to groundwater in Appendix 1 to match county soil survey alpha to numeric name changes. Copies of these documents are available at the following web address: http://www.datcp.state.wi.us/arm/agriculture/land-water/conservation/nutrient-mngmt/planning.jsp

How can nutrient management plans comply with UWEX Publ. A2809 (1998), when the DATCP certified soil testing laboratories will be following A2809 (2006)?

- The soil test recommendations provided by DATCP certified laboratories will be updated to include the UWEX Publ. A2809 (2006) on January 1, 2007. The major change in these recommendations allows farmers a choice to minimize corn inputs based fertilizer N and corn price ratios appropriate for the operation. Nutrient management planners can still choose the high end of this range, which is equal to A2809 (1998) levels.

- Nutrient applications based on the field's soil tests can be calculated manually or by using *Snap-Plus* nutrient management software from http://www.snapplus.net/ developed by the UW Madison, Department of Soil Science and available free of charge. A new version of *Snap-Pl*us that will use the most current UWEX Publ. A2809 (2006) application rate guidelines will be released in February or March 2007. The high end of the N rate guidelines at the 0.05 N: corn price ratios will be the "default" values in *Snap-Plus*. This would give the maximum amount of N to apply that is approximately equal to the rate needed to maximize yield. However, users will also be able to adjust their application rate for current economics and select other fertilizer N: corn price ratios to maximize economic return in any specific year.

In what situations can the nutrient management plan deviate from A2809 soil test recommendations?

- When soil or tissue test reveals a specific deficiency.
- When excess nutrients are the result of an unforeseen change in the type of crop planted.
- When excess nutrients are the result of manure applications made in the last year prior to implementing the plan.
- When organic N (legumes, manure, organic byproducts) is used to meet the entire N requirement an additional 20% can be added to the recommended N rate.
- When organic N is applied to the removal rate or less of the upcoming year's legume crop.
- When corn after corn with >50% residue was not considered in the soil test, add 30 pounds N per acre.
- When organic P (manure, organic byproducts) is applied during a crop rotation (up to 8 years), and P is managed using either the *Soil test P management strategy* OR the *WI P-Index* model found in *Snap-Plus*. See http://www.snapplus.net/ software.

- When other special agronomic conditions are documented by the planner. However, applications in excess of UW recommendations must not materially increase environmental damage.

What are the manure application restrictions in the 590 standard (2005)?

- No mechanical manure applications within 50 feet of drinking water wells.
- No nutrient applications within waterways, non-harvested areas, sinkholes, or nonmetallic mines.
- No nutrient applications within 200 feet upslope of groundwater conduits such as sinkholes, fractured bedrock, tile inlets, non-metallic mines or wells unless incorporated into the soil within 72 hours (except for manure deposited by grazing animals).
- No nutrient applications on fields eroding at rates that exceed tolerable soil loss (T).
- No mechanical manure applications on frozen or snow-covered soils within 1000' of lakes & 300' of perennial streams. On frozen or snow-covered soils do not apply manure in excess of 7,000 gallons per acre or the P removal of the next crop, whichever is less.
- On frozen or snow covered soils do not apply manure on slopes greater than 9% (12% for contour farming).
- Manure applications must comply with supplementary local winter spreading restrictions, if any, spelled out in an individual farm conservation plan agreed upon between the farmer and the county land conservation committee.
- On frozen or snow covered soils do not apply commercial fertilizer except on grass pastures and winter grains.
- On soils likely to leach nitrate nitrogen listed in the *Wis. Conservation Planning Technical NoteWI-1*, and areas within 1000' of a municipal well, apply most of the N in the spring. See http://www.snapplus.net/ to highlight which soils on the farm are susceptible to leaching N.

Is soil erosion control required as part of a nutrient management plan; and can *Snap-Plus* software be used to develop this part of a conservation plan?

Yes. The nutrient management plan must control sheet and rill soil erosion to tolerable levels (T) and provide treatment of ephemeral and gully soil erosion. Sheet and rill soil erosion control can be calculated using *Snap-Plus* software, while ephemeral and gully soil erosion control may require leaving more plant residue or establishing grassed water ways in addition to the *Snap-Plus* calculations. A conservation plan should also try to reduce runoff events from winter applied manure by identifying high risk fields where runoff concentrates or could flow to groundwater conduits.

How do I determine the manure nutrient values for a nutrient management plan?

These values must be based on either:

1. Manure analysis conducted at a laboratory that participates in the manure analysis proficiency program. See DATCP Certified Soil Testing Laboratories at http://www.datcp.state.wi.us/arm/agriculture/land-water/conservation/nutrient-mngmt/planning.jsp or
2. Standard "book values" contained in *WI Conservation Planning Tech Note WI-1*. This information is also found in the *Snap-Plus* nutrient management software from http://www.snapplus.net/.

IS FALL DEEP BANDED FERTILIZER PLACEMENT SUPERIOR?

Richard P. Wolkowski [1/]

Introduction

Grain crop producers continue have interest in P and K fertilizer placement for several reasons. Issues include: (1) the need at high soil test, (2) alternatives to 2x2 because of planter attachment cost, (3) fertilizer use efficiency, (4) convenience/time limitations, and 5) potential yield benefits. Research has demonstrated that banded placement methods enhance the efficiency of nutrient use and can increase yield. This observation appears to be more important in high residue management systems where nutrient applications are not routinely incorporated. Research conducted by this author has demonstrated increased P and K uptake and yield where the planter 2x2 placement method is used compared with broadcast (Wolkowski, 2000; 2003). Response tended to be greater in no-till relative chisel because soil and environmental condition of the seedbed under no-till resulted in reduced early season plant growth and nutrient uptake.

Recent increases in cropping input costs have spurred interest in reduced tillage sys-tems that will not compromise productivity. True no-till (slot planting) has not been success-ful in Wisconsin because of our cool, wet spring soil conditions and therefore most producers have adopted some form of in-row residue management to modify soil conditions the seed zone. Strip-tillage popularity has increased because it overcomes some of the common problems associated with no-till planting such as imperfect planter slot closure, hair-pinning of residue, cool/wet seed zone conditions, and surface compaction. Strip-tillage buries slightly more residue than no-till, but still offers a better soil conservation alternative than most full-width tillage systems. Strip tillage, like many practices, has many variations of practice and hence some definitions are needed. Strip tillage for the purposes of this paper is considered to be tillage of an 8- to 10-inch wide area of the soil using attachments that move residue from this zone, run a mole knife 6 to 8 inches deep, and then form a berm of 2 to 4 inches in height. Typically the operation is done in the fall in fragile residue such as soybean or fall-killed alfalfa. Corn residue commonly plugs the strip tillage tool. The crop is planted over the center of the strip the following spring. Modern setups employ steering guidance systems to establish the strips and then facilitate planting on them the following year.

Several dealerships now offer a custom strip-tillage service that can be accompanied by the deep placement of fertilizer in the future row area. It has been suggested that fall application may eliminate the need for row fertilizer in the spring and avoid the delays and expense that are associated with spring fertilizer application with the planter. The suggestion has been made that deep placement may offset concerns with nutrient stratification in no-till. Several Midwestern research studies have compared the deep placement of fertilizer to other methods of application. Most of the focus of the research was on P and K. While N could be applied with deep banding equipment on strip tillage tools, its application in the fall would not be recommended in Wisconsin because of the relative inefficiency of fall N fertilization.

Fertilizer Placement Methods

Methods of P and K fertilizer placement include: (1) broadcast — with or without incorporation, (2) banding — on the surface, with the seed, near the seed, or at some depth, (3) foliar — most appropriate with micronutrients. The selection of the method will depend on several factors including soil test level, crop, tillage management, equipment limitations, soil and residue condition,

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time constraints, and rate. Deep placement is considered by some to be a recent innovation; however it is clear from a review of the literature (Randall and Hoeft, 1988) that researchers have studied it for at least the last 50 years.

Randall and Hoeft (1988) describe the four broad objectives of a fertilizer placement decision to be: (1) the method promoting the most efficient nutrient use by the plant, (2) the prevention or reduction of nutrient loss resulting in environmental contamination, (3) avoidance of damage to the plant, and (4) the provision of an economical and convenient practice. Banding is generally accepted as the most efficient placement in terms of nutrient use, the safest method with respect to nutrient loss to the surface water, and of little risk to the plant as long as seed placement is not used. This leaves the fourth consideration – economics and convenience, which often trumps agronomics with respect to the final placement decision. They conclude that economic yield response of corn to P and K seldom occur at high or excessively high soil test levels and that at responsive soil test levels banding generally outperforms broadcast. It has been shown that crop rooting is enhanced in the banded zone and is likely responsible for the early growth observed with such treatment. Kaspar et al. (1991) demonstrated that banding in the row nearly double the root length of corn measured in the top 6 inches in the row compared to banding in the inter-row. Early season crop response to banded fertilizer does not always translate into an economic yield response, especially in years when adequate heat units are available.

The type of banding method selected is dependent upon its cost, equipment availability, cropping system, and soil conditions. Conceivably there could be an economic advantage to fall deep placement with a strip-till machine when factors related to equipment availability, planter attachment cost, time, and soil conditions are considered. The focus of this paper is to examine regional research that has compared fall deep banding in a strip-till system with broadcast or planter-placed methods.

Research Comparisons

Arlington, Wis.

A tillage/rotation study was established by the author in 1997 on a Plano silt loam soil at the Arlington Agricultural Research Station. The main plot treatment is rotation (continuous corn, soybean/corn, and corn/soybean). These treatments are subdivided into tillage subplot treatments (fall chisel/spring field cultivator, strip-till, and no-till). These treatments were maintained from 1997-2000 and the plots did not receive additional P and K fertilizer until the fall of 2000 when the current sub-subplot fertilizer placement treatments were installed. A rate of 200 lb/a of a 9-23-30 material was applied as a fall broadcast prior to primary tillage, in the row on a 2x2 placement at planting, and 6 to 8 inches deep in the strip-till treatment only. This rate of P and K approximates the UWEX recommendation for a 175 bu/a corn grain yield. An unfertilized treatment is also included. Tillage and fertilizer treatments were similar in corn and soybean each year. All treatments are replicated four times in a split-split plot treatment arrangement. Only the results of the strip till treatments for 2001 to 2004 will be discussed in this paper.

Strip-tillage was conducted in the fall with a tool that features finger coulters, a ripple coulter, a mole knife that runs 7 to 8 inches deep, all followed by closing disks that form a ridge about 3 inches high. Strips were alternated between rows each year and the succeeding crop was planted on the ridge the next spring in 30-inch rows. A Gandy air-delivery fertilizer system was mounted on the tool to meter the deep fertilizer placement. A full season corn hybrid (RM 105 days) or soybean variety (zone 2.1) was planted in early May. UWEX recommendations were followed for all non-treatment crop production inputs including pest management and supplemental N.

Table 1 shows the average soil test values (0 to 8 inches) for the strip-till treatments averaged over all crop rotations. The samples were collected after one fertilization event in 2001 and five fertilization events in 2005. These data show that drawdown from fertilization was similar to the increase observed where fertilizer was broadcast. Soil test P remained in the excessively high category after five seasons in all situations. Soil test K decreased slightly in the unfertilized treatment, but remained in the optimum category; however the soil test K in the broadcast treatment increased into the high category. Soil samples were not collected from either banded treatment (2x2 or deep placed).

Table 1. Average soil test values for the strip tillage plots in the Arlington rotation x tillage Study, 2001 and 2005, Arlington, Wis. †

Year	pH		Soil test P (ppm)		Soil test K (ppm)	
	None	Broadcast	None	Broadcast	None	Broadcast
2001	6.7	6.7	41	51	99	110
2005	6.7	6.6	38	56	91	120

† Values are the average of 0- to 2-inch incremental samples averaged over an 8-inch sample depth. Averaged over all crop rotations. Annual broadcast application: 200 lb 9-23-30/a.

One way to evaluate the responsive to P and K fertilizer placement methods is to measure the early season uptake by the crop. The uptake of P and K at about 45 days after planting (tallest corn at V6) is shown in Table 2. Uptake is the product of dry matter accumulation and plant tissue nutrient concentration. The uptake values shown in Table 2 are presented as mg nutrient (elemental basis) per plant. Rotation affected uptake in some years, possibly due to warmer soil conditions in the SbC treatment due to lower surface crop residue. The corn plants were often larger in this treatment. Fertilizer placement affected the nutrient uptake of both P and K in all years with the exception of P in 2002, which was significant at the p=0.10 level. Differences appeared to be the greatest where material was applied on a 2x2 placement with the planter compared to either broadcast or deep, although there were situations where there were no apparent differences in P and K uptake with respect to placement. This is likely due to the fact that fertilizer is placed the closest to the seed in the 2x2 method. Additionally, the broadcast and deep placement treatments are applied six months prior to planting, which could have resulted in more fixation of P and K by the soil. These results generally show that P and K uptake from deep placement was similar to that of broadcast, and does not demonstrate an advantage over planter placed material.

While it is apparent that deep placement was generally inferior in terms of early season nutrient utilization there still could be an advantage to this placement method as long as the applied nutrients were eventually utilized and yield was not affected. Table 3 presents the corn and soybean grain yields for 2001–2004. Rotation did not significantly affect corn yield in any year, but there was a strong trend each year for higher yield in first-year corn after soybean compared to continuous corn. Fertilizer placement did not affect corn yield in any year. Trends appeared to vary between continuous corn and first-year corn such that the 2x2 placement performed better in continuous corn, but not as well as the other placement methods in first-year corn. The relative responsiveness to fertilization appeared to be higher in first-year corn, compared to continuous corn. Soybean yield was more consistently affected by placement; however the effect varied between years and differences were relatively small. Overall these data do not demonstrate the superiority of any specific placement method with respect to grain yield over the 4 years of the study.

Table 2. Uptake of P and K by corn 45 days after planting as affected by fertilizer placement in strip-tillage, 2001 - 2004, Arlington, Wis.

		Year							
		2001		2002		2003		2004	
Rotation	Placement	P	K	P	K	P	K	P	K
		mg/plant							
CC	None	21	102	6	32	15	80	14	102
	Broadcast	23	102	10	73	17	103	15	120
	2x2	27	188	10	81	17	124	18	155
	Deep	19	100	7	57	17	116	13	100
SbC	None	30	84	9	38	13	31	15	65
	Broadcast	27	123	12	84	20	83	17	122
	2x2	33	171	12	91	19	93	20	152
	Deep	26	127	12	94	17	75	17	101
Pr>F	Rotation	<0.01	0.88	0.12	0.38	0.47	0.04	0.09	0.47
	Placement	<0.01	<0.01	0.08	<0.01	0.01	0.05	0.03	<0.01
	R*P	0.49	0.31	0.70	0.67	0.17	0.86	0.67	0.55

Table 3. Corn and soybean grain yield as affected by fertilizer placement in strip-tillage, 2001–2004, Arlington, Wis.

		Year				
Rotation	Placement	2001	2002	2003	2004	Average
		bu/a				
CC	None	181	172	148	173	169
	Broadcast	182	173	131	177	166
	2x2	182	179	137	183	170
	Deep	179	169	139	165	163
SbC	None	199	192	161	184	184
	Broadcast	210	218	200	203	208
	2x2	204	206	194	196	200
	Deep	207	217	199	186	202
Pr>F	Rotation	0.07	0.11	0.18	0.11	
	Placement	0.79	0.17	0.40	0.24	
	R*P	0.79	0.19	0.02	0.81	
CSb	None	57	50	34	55	49
	Broadcast	60	50	34	55	50
	2x2	--†	52	30	54	45
	Deep	61	53	31	50	49
Pr>F	Placement	0.09	0.76	0.09	0.05	

† The 2x2 placement was not included for soybean in 2001.

Iowa

Antonio Mallarino and his students conducted extensive studies of fertilizer placement for no-till for corn following soybean in both small plot and on-farm trials over a three year period (Mallarino et al., 1999). They examined response to P and K separately by applying non-limiting rates of one of these nutrients with two rates of the nutrient in question. They found that the planter-placed fertilizer increased early-season plant weight more than the other placements (data not shown). Early season growth responses to P were more common than to K. A summary of the yield effects of fertilizer placement for this work is shown in Table 4. The studies conducted in small plots at regional research centers did not show differences with respect to the placement of P, however the deep placed K significantly increased yield over the broadcast and planter placed treatments by 4 bu/a. Similarly the on-farm comparisons did not show a response to P, but deep K placement increased yield by 4 bu/a compared to broadcast. Planter-placed treatments were not evaluated in the non-farm studies. They conclude that the early season growth response seen with P did not guarantee a yield response, and likewise the lack of an early season response as seen with K did not preclude a significant yield response. Their data also show that a small part of the response to deep placement may be the result of the knife itself, independent of fertilization; however the difference is relatively small.

Table 4. Response of first-year corn following soybean to fertilizer placement in Iowa, (adapted from Mallarino et al., 1999).

		Placement				.
Nutrient	Control	Deep w/o	Broadcast	Deep	2x2	Pr>F
		---------- bu/a ----------				
Small plots						
P	137	139	143	145	144	0.76
K	145	142	146	150	146	0.01
On-farm						
P	136	138	144	142	N/A	0.24
K	136	138	142	146	N/A	0.02

Ontario

Vyn and Janovicek (2001) examined the response of corn following wheat at two locations in southeast Ontario, Canada. Growing conditions in that region are similar to those in Wisconsin. The soils had medium to high soil test K. Their study compared K rates in fall moldboard plow, fall strip-tillage, and no-till on soils having medium to high soil test K. Fall K was broadcast and incorporated in the plow, placed six in. deep in strip-tillage, and fall surface broadcast in the no-till. Plots were further split to include with and without treatment with spring planter-placed starter K (2x2). A summary of the corn grain yield for the Kirkton location is shown in Table 5. These data show that in all tillage treatments corn yield was increased by fall K when row fertilizer was not applied. If row fertilizer was applied an increase was only observed in moldboard. Deep K placement in strip-till increased yield in the absence of row K from 149 to 154 bu/a; however starter alone (no fall K) produced 157 bu/a. It can be argued that strip-till at modest rates of K (45 lb K_2O/a) produced yields nearly as large as those with planter-placed fertilizer alone when soil test K levels are responsive.

Table 5. Response of corn to K fertilizer placement at Kirkton, Ontario, three-year average. (adapted from Vyn and Janovicek, 2001).

	Tillage and row K rate (lb K_2O/a)					
	No-till		Strip-till		Moldboard plow	
Fall K rate	Low	High	Low	High	Low	High
lb K_2O/a	----------------------------------- bu/a	-----------------------------------				
0	148	161 **	149	157 **	158	162
45	157	160	151	158 **	161	164
90	155	161 **	154	155	164	170 **
Deep sig.	**	NS	+	NS	*	**

Row K in the Low treatment was 10 lb K_2O/a in year one and 0 lb K_2O/a in years two and three.
+, *, ** = significant at the 0.10, 0.05 and 0.01 level, respectively.
Deep significance compares response to deep placement within a tillage and row K rate.
Row significance shown between low and high row K within tillage treatments.

Minnesota

Researchers in Minnesota examined the response of corn to deep placement of K fertilizer in long-term ridge-till at three locations (Rehm and Lamb, 2004). Soil tests at all sites were greater than 140 ppm K (1 M ammonium acetate), and were categorized as high or excessively high with respect to K availability. Their evaluation did not show a relationship between yield and K rate for corn or soybean at any of the locations (Table 6). Potassium fertilization did increase the K concentration in corn earleaf at one of the three locations, but did not affect the K concentration in soybean leaves at the R1 growth stage. They concluded that deep placement of K is not a universal requirement for crop production in ridge-till, especially at high soil test levels.

Table 6. Response of corn and soybean to deep K fertilizer placement in long-term ridge-till at three Minnesota locations, (adapted from Rehm and Lamb, 2004).

	K rate (lb K_2O)/a					.
Crop	0	20	40	60	80	Pr>F
	----------------------------------- bu/a	-----------------------------------				
Corn						
Blue Earth	152	161	162	158	165	NS
Dodge	182	174	183	188	180	NS
Pope	168	168	169	173	162	NS
Soybean						
Blue Earth	38	36	36	39	32	NS
Dodge	53	53	54	52	52	NS
Pope	42	40	42	42	41	NS

Summary

Is fall deep banded fertilizer superior – the answer is no with respect to crop yield response. However there may be circumstances where this placement method for P and K may be favorable over broadcast and row-placement. Fall deep placement of N is not recommended because of the proven inefficiency of this practice. Advantages will be based on economics related to application cost and the time management considerations of the grower. Like any placement method response is most probable at optimum or lower soil test P and K levels and is likely coupled with growing season degree day accumulation. Deep banding does not appear to provide the same early season response that is observed with the traditional 2x2 placement, but will increase the uptake of P and K relative to the control. It can be assumed that corn eventually utilizes these nutrients and yield will be relatively unaffected by fertilizer placement. The use of deep placement in strip-tillage systems is a viable method of applying P and K at rates equivalent to or less than crop removal. At low and very low soil test levels some of the P and K should be broadcast to uniformly increase soil test. Deep placement has not been evaluated in full width tillage systems such as chisel or moldboard plowing and its benefit in those systems is unknown. Growers need to consider planter attachment costs and practicality when choosing a placement system for P and K. Recognize that soil sampling fields that have received deep banded fertilization may result in variable soil test levels if an inadequate number of cores and samples are collected.

References

Kaspar, T.C., H.J. Brown, and E. M. Kassmeyer. 1991. Corn root distribution as affected by tillage, wheel traffic, and fertilizer placement. Soil Sci. Soc. Am. J. 55:1390-1394.

Mallarino, A.P., J.M. Bordoli, and R. Borges. 1999. Phosphorus and potassium placement effects on early growth and nutrient uptake of no-till corn and relationships with grain yield. Agron. J. 91:37-45.

Randall, G.W., and R.G. Hoeft. 1988. Placement methods for improved efficiency of P and K fertilizers. J. Prod. Agric. 1:70-79.

Rehm, G.W., and J.A. Lamb. 2004. Impact of banded potassium on crop yield and soil potassium in ridge-till planting. Soil Sci. Soc. Am. J. 68:629-636.

Vyn, T.J., and K.J. Janovicek. 2001. Potassium placement and tillage system effects on corn response following long-term no-till. Agron. J. 93:487-495.

Wolkowski, R.P. 2000. Row-placed fertilizer for maize grown with an in-row crop residue management system in southern Wisconsin. Soil Tillage Res. 54:55-62.

Wolkowski, R.P. 2003. Wisconsin corn and soybean responses to fertilizer placement in conservation tillage systems. Proc. Wis. Fert. Aglime, and Pest Mgt. Conf. 42:99-106.

GETTING FULL VALUE FROM TISSUE TESTING

John B. Peters[1]

Tissue testing is the quantitative measurement of the essential elements in plant tissue. Plants require 17 elements for normal vegetative growth and reproduction. These elements fulfill a variety of functions in plants and are required at varying levels by different plant species. Carbon, hydrogen and oxygen are not analyzed because they come from the air or water and virtually are never limiting to plant growth. Of the remaining 13 elements that come from the soil, chlorine is normally not analyzed because it is always sufficient under Wisconsin conditions. As a result, tissue testing or plant analysis, usually refers to the analysis for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (B), and molybdenum (Mo). Aluminum (Al) and sodium (Na) are normally included even though they are not essential elements. Aluminum can be toxic in acid soils, and sodium improves the quality of some crops.

Results of tissue testing along with a soil test can provide a valuable guide to more efficient crop production. Soil tests provide a good estimate of lime and general fertilizer needs. By adding tissue analysis data, the user is able to better evaluate fertilizer and management practices more accurately by providing a thorough nutritional view of the crop. Several key uses of plant analysis include: evaluation of fertilizer efficiency, determination of availability of elements for which reliable soil tests are not available, and the ability to evaluate the interaction among plant nutrients. In a healthy plant, all essential elements are present at appropriate levels and in proper proportions relative to each other. Plant growth is restricted when: not enough of one or more elements is present; too much of one or more elements is present, including toxic levels of nonessential elements such as aluminum, arsenic, selenium, or sodium; or the levels of one or more elements is adequate but out of balance with other elements.

Typically, the first result of nutrient deficiency, toxicity or imbalance is a reduction in the growth of the plant. If the condition worsens, visible deficiency symptoms appear and plant yield is further reduced. Severe deficiencies or toxicities can kill plants or weaken them to the point that they are more vulnerable to other stresses, such as disease or insect attack.

Sampling

Collecting a proper sample is critical for plant tissue analysis as plant nutrient composition varies with age, the portion of the plant sampled, and many other factors. Mistakes or carelessness in selecting, collecting, handling, preparing, or shipping plant tissue for analysis can result in unreliable data, which may lead to incorrect interpretations and recommendations. The standards against which the samples are evaluated, have been selected to represent the plant part and time of sampling that best define the relationship between nutrient composition and plant growth. Deviating from the prescribed protocol severely limits the ability to interpret results. Therefore, it is critical to follow a standard sampling procedure.

Table 1 lists the proper stage of growth, plant part, and number of plants to sample for some key agronomic and horticultural crops. If the tissue sample is collected at any other time in

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the growing season, it may not be possible to interpret the results properly. However, when plant analysis is being used to confirm a suspected nutrient deficiency, the samples should be taken as early in the season as possible so that the deficiency can be corrected and minimize the potential yield loss. Plants showing abnormalities usually continue to accumulate nutrients even if growth is impaired by some limiting factor. Samples should not be taken from plants that obviously have been stressed from causes other than nutrients. Do not take samples from plants that; 1) are dead or insect damaged, 2) are mechanically or chemically injured, 3) have been stressed by too much or too little moisture, or 4) have been stressed by abnormally high or abnormally low temperature.

When a nutrient deficiency is suspected, or there is a need to compare different areas in a field, it is recommended that similar plant parts be collected separately from both the affected plants and adjacent normal plants that are at the same stage of growth. In this way, a better evaluation can be made between the nutritional status of healthy and abnormal plants of the same variety grown under the same conditions.

Tissue Sample Handling

After a plant sample has been collected, it should be prepared for shipment or delivery to the laboratory. Roots or foreign material attached to the sample should be removed and discarded. Plant tissue must then be dusted off to remove soil particles. Tissue samples should never be washed since soluble nutrients will be leached out of the sample. If a tissue sample is to be mailed, the sample should be air dried at least one day to avoid mold formation during shipment. Never mail samples late in the week, since the tissue will deteriorate in the post office over the weekend. Place the plant sample in a large paper envelope for shipment. Do not place tissue samples in plastic or polyethylene bags since plant tissue molds more rapidly in these air-tight types of bags. Plant samples that are delivered to the lab do not need to be air dried if they are delivered within one day of collection.

Soil Sampling

Soil test results for pH, organic matter, phosphorus and potassium can be useful for helping to correlate tissue analysis results to nutrient deficiency or toxicity. A soil sample consisting of 10 or more cores should be collected from the same area where the plant sample was taken. For row crops, such as corn, avoid the fertilizer band by sampling in the middle of the row. Label the soil sample with the same field and sample number as that assigned to the tissue sample. Package corresponding plant and soil samples together, making sure that the bags are properly closed so that they will not open in transit and allow the soil to contaminate the tissue sample.

Interpretation of Tissue Analysis Values

Depending on the crop, plant part and stage of growth sampled, there are a number of ways in which tissue analysis data is reported and interpreted. The UW Soil and Plant Analysis Laboratory uses three approaches for interpreting tissue analysis results. These include the use of a sufficiency range approach (SR), the diagnosis and recommendation integrated system approach (DRIS), and the plant analysis with standardized scores (PASS) system. Essentially, the SR approach looks at one element at a time using critical levels for that element. The DRIS system uses two or more elements at a time to develop an index. PASS attempts to combine the fixed and variable features of the SR and DRIS systems.

The SR system uses the critical level approach in which the critical level corresponds to 90 to 100% of maximum yield on a yield vs. nutrient concentration graph. The sufficiency approach interprets the plant nutrient levels as being in a range considered to be adequate (sufficient) or below (deficient) or above that range (high). The advantages of this approach include that it is simple to determine and interpret and the values are independent as the level of one nutrient does not affect the classification of another nutrient. Some disadvantages include the fact that there are too few categories to adequately distinguish a low from a very low for example, it does not rank the nutrients to determine which is most limiting, it is very sensitive to plant maturity and plant part sampled. The following crops can be interpreting by SPAL using the sufficiency approach. Alfalfa; apple; asparagus; barley; bean, dry; bean, lima; bean, snap; beet, red; black oak; blueberry; bluegrass; broccoli; brome grass; brussel sprouts; buckwheat; cabbage; canola; carrot; cauliflower; celery; cherry; cranberry; cucumber; fescue, fine; field corn; ginseng; grape; lettuce; lupine; millet; mint; muskmelon; oat; onion; orchard grass; pea, canning; pea, chick; pepper; post oak; potato; pumpkin; raspberry; red clover; red clover hay; rye; sorghum, grain; sorghum-sudan; soybean; spinach; squash; strawberry; sugar beet; sunflower; sweet corn; tobacco; tomato; trefoil; triticale; vetch, crown; watermelon; and wheat.

The DRIS system is based on taking the ratio of all possible pairs of nutrients. These sample ratios are compared with ratios that are normal for high-yielding crops using a relatively complicated standardization formula. The standard scores for each nutrient are averaged to get one index per nutrient. Zero is the optimum, while negative index values indicate that the nutrient level is below optimum and the more negative the index the more deficient the nutrient. Similarly, the more positive the index, the more excessive the nutrient is above normal. The advantages of DRIS include that the nutrients are ranked from most deficient to most excessive and the scale is continuous and easily interpreted. Disadvantages include that the computations are complicated and the indices are not independent. Because of this, the level of one nutrient can have a marked effect on the other indices. DRIS interpretations can be made by SPAL for alfalfa; apple; field corn; lettuce; and soybeans.

The PASS system is a hybrid system that has two components. One is based on the independent nutrient index approach as in the SR system, and the other based on a dependent nutrient index approach as in the DRIS system. In Wisconsin, data is available to perform PASS analysis on alfalfa; field corn; and soybeans.

Summary of Sufficiency Range Results

The results for tissue analyses performed at the UW Soil and Plant Analysis Laboratory in the past four years are summarized in Tables 2 to 7. Only the results of plant materials that were tested at least 25 times or more are included in these tables. Since plant analysis is used as the primary guide for making nutrient application recommendations for fruit crops, it is not surprising to see many of the most commonly grown fruit crops on this list. In addition, the dominant agronomic crops for the state are also represented as tissue testing is used to help diagnose nutrient deficiencies or imbalances for these crops under certain circumstances.

Since most crops require significant amounts of nitrogen, and N does not normally carry over to any significant extent from one growing season to another, it might be expected that plant analysis may often show N levels to be below the sufficiency range. The results do indicate that N is the most commonly deficient element if the median lab values are compared to the sufficiency level for various crops. Also, the very low minimum values found in Table 2, indicate that N can be very limiting to crop production under certain conditions as some of these values are extremely low when compared to the level required for sufficiency. The median value for tissue N is below the sufficiency range for field corn, grape, strawberries, and soybeans. Since soybean is a legume, the lower than expected N levels are probably related to poor nodulation or other factors limiting growth. In looking at the other macro-nutrients, secondary and micro-nutrients, S and Zn are the two that show the greatest frequency of the median value for tested samples falling into the deficient range. A number of crops show tissue levels of Fe and Cu below what is considered to be sufficient, but this is likely related to other issues as these nutrients are not commonly applied as fertilizer amendments under Wisconsin conditions.

Summary

The use of plant tissue testing as a tool in helping to more efficiently manage crop production in Wisconsin is relatively limited. In general, tissue testing is most common on relatively high value horticultural crops, such as cranberries and apples and much less common on traditional agronomic crops such as alfalfa and corn. The use of the technology also differs as tissue testing is used routinely to guide nutrient applications on horticultural and fruit crops, but when used on more traditional agronomic crops such as corn or alfalfa, it is normally to help diagnose a plant production problem. Of the three methods of interpreting results, the use of the sufficiency range is by far the most common as DRIS and PASS norms are only available for a small number of crops. When sampled properly, a tissue sample can be an extremely valuable tool to diagnose plant nutrient problems that would not be apparent with soil testing alone. Even if no SR norms are available for a crop, tissue testing can be used by comparing plants with normal and abnormal growth when sampled and tested separately.

The key to tissue testing is to take a good, representative sample from the proper part of the plant, at the correct stage of growth, and handle the sample properly. Remember to include a soil sample to aid in the interpretation of the results and the diagnosis of the problem, if one exists.

References

Baldock, J.O., and E.E. Schulte. 1996. Plant analysis with standardized scores combines DRIS and sufficiency range approaches for corn. Agron. J. 88:448-456.

Beverly, R.B. 1991. A practical guide to the Diagnosis and Recommendation Integrated System. Micro-Macro Publ., Athens, GA.

Kelling, K.A., S.M. Combs, and J.B. Peters. 2002. Sampling for plant analysis. UWEX Bull. Univ. of Wisconsin-Extension, Madison, WI.

Mills, H.A., and J.B. Jones, Jr. 1996. Plant analysis handbook II. Micro-Macro Publ. Inc., Jefferson City, MO.

Table 1. Recommended stage of growth, plant part and sample size for tissue testing.

	Stage or growth	Plant part	No. of plants to sample
<u>Field crop</u>			
alfalfa	bud to first flower	top 6 inches	35
alfalfa	harvest	whole plant	25
barley	prior to heading	newest fully developed leaf	50
bluegrass	prior to heading	newest fully developed leaf	50
bromegrass	prior to heading	newest fully developed leaf	50
corn, field	12 inches tall	whole plant	20
corn, field	pre-tassel	leaf below whorl	15
corn, field	tassel to silk	ear leaf	15
pea, canning	prior to or at initial flower	newest fully developed leaf	25
potato	prior to or at initial flower	4th petiole and leaflet	40
potato	tuber bulking	4th petiole and leaflet	40
red clover	bud to first flower	top 6 inches	35
soybean	prior to or at initial flower	newest fully developed leaf	25
wheat	tillering - prior to heading	newest fully developed leaf	50
<u>Veg crop</u>			
beet, red	mid-season	youngest mature leaves	20
cabbage	mid-season	wrapper leaves	20
carrot	mid-season	youngest mature leaves	20
ginseng	mid-season	youngest mature leaves	35
onions	mid-season	tops, no white portion	20
squash	prior to or at early fruit development	newest fully developed leaf	25
tomato	mid-season	newest fully developed leaf	40
<u>Fruit crop</u>			
apple	current season shoots (July 1-15)	fully developed leaf at mid-point of new shoots	4 lvs
blueberry	new summer growth	fully developed leaf	35
cherry, sour	current season shoots (July 1-15)	fully developed leaf at mid-point of new shoots	4 lvs
cranberry	Aug 15 - Sept 15	current season growth above berries	200 uprights
grape	full bloom	newest fully developed petiole	5 from each of 10 vines
raspberry	Aug 10- Sept 4	6th and 12th leaf blade and petiole from tip	2-3 lvs from 10 canes
strawberry	at renovation before mowing	fully developed leaflets and petioles	40

The units for the numbers in Tables 2-4 are percent (%); the units for Tables 5-7 are parts per million (ppm)

Table 2.

	Nitrogen				Phosphorus			
Crop	Min	Max	Median	Sufficiency range	Min	Max	Median	Sufficiency range
Cranberry	0.04	2.80	0.90	0.9 - 1.1	0.08	1.17	0.14	0.1 - 0.2
Apple	0.93	3.22	2.06	1.9 - 2.2	0.12	2.24	0.19	0.20 - 0.21
Field corn- tassel	0.46	3.66	2.61	2.50 - 3.33	0.10	1.17	0.33	0.25 - 0.34
Field corn- 12" tall	1.24	5.26	2.98	3.5 - 5.0	0.14	0.87	0.42	0.3 - 0.5
Alfalfa	0.07	5.85	3.31	2.5 - 4.0	0.14	0.75	0.40	0.25 - 0.45
Soybean	0.48	6.26	3.75	4.2 - 5.4	0.08	2.11	0.40	0.3 - 0.7
Field corn	0.76	4.09	2.97	3.0 - 3.5	0.21	3.04	0.41	0.25 - 0.45
Grape	0.45	3.42	0.74	0.85 - 1.25	0.03	0.69	0.28	0.14 - 0.30
Strawberry	1.10	2.88	1.73	2.1 - 2.9	0.18	0.45	0.26	0.24 - 0.30
Blueberry	0.91	2.15	1.66	1.7 - 2.1	0.07	0.80	0.11	0.1 - 0.4
Cherry	1.80	3.81	2.42	2.1 - 2.6	0.12	0.28	0.21	0.20 - 0.25

Table 3.

	Potassium				Calcium			
Crop	Min	Max	Median	Sufficiency range	Min	Max	Median	Sufficiency range
Cranberry	0.31	1.90	0.52	0.4 - 0.75	0.15	9.91	0.83	0.3 - 0.8
Apple	0.43	10.3	1.18	1.0 - 1.6	0.42	9.96	1.12	0.6 - 1.0
Field corn	0.35	4.27	2.01	1.75 - 2.63	0.16	0.96	0.51	0.30 - 0.55
Field corn	0.38	5.45	2.87	2.5 - 4.0	0.04	1.61	0.43	0.3 - 0.7
Alfalfa	0.38	4.19	2.49	2.25 - 3.5	0.60	3.65	1.36	0.7 - 2.5
Soybean	0.37	3.87	2.30	2.15 - 3.25	0.34	2.99	1.10	0.8 - 1.3
Field corn	0.19	5.21	2.70	2.0 - 2.5	0.11	1.06	0.41	0.25 - 0.50
Grape	0.23	4.47	1.22	1.2 - 2.5	0.15	2.81	1.56	1.2 - 2.5
Strawberry	1.00	2.17	1.63	1.2 - 1.7	0.46	1.54	0.89	0.6 - 1.0
Blueberry	0.34	1.31	0.56	0.4 - 0.7	0.28	0.66	0.45	0.35 - 0.80
Cherry	0.60	2.30	1.61	1.0 - 1.6	0.91	2.44	1.66	0.6 - 1.0

Table 4.

	Magnesium				Sulfur			
Crop	Min	Max	Median	Sufficiency range	Min	Max	Median	Sufficiency range
Cranberry	0.09	0.40	0.22	0.15 - 0.25	0.05	1.12	0.12	0.08 - 0.25
Apple	0.16	0.94	0.34	0.3 - 0.5	0.08	0.22	0.15	0.14 - 0.18
Field corn	0.06	1.27	0.27	0.16 - 0.34	0.10	0.39	0.20	0.16 - 0.25
Field corn	0.06	1.68	0.30	0.15 - 0.45	0.08	0.90	0.20	0.15 - 0.50
Alfalfa	0.16	1.20	0.40	0.25 - 0.70	0.09	0.55	0.31	0.25 - 0.50
Soybean	0.19	1.54	0.49	0.23 - 0.55	0.08	0.41	0.27	0.38 - 0.50
Field corn	0.11	1.66	0.28	0.13 - 0.30	0.10	39.7	0.23	0.15 - 0.50
Grape	0.10	1.95	0.89	0.3 - 0.5	0.05	0.27	0.12	0.15 - 0.25
Strawberry	0.24	0.53	0.34	0.3 - 0.5	0.08	0.92	0.12	0.14 - 0.18
Blueberry	0.11	0.24	0.15	0.12 - 0.25	0.11	0.61	0.14	0.12 - 0.30
Cherry	0.33	0.87	0.62	0.3 - 0.5	0.12	0.19	0.14	0.14 - 0.18

Table 5.

Crop	Zinc Min	Zinc Max	Zinc Median	Zinc Sufficiency range	Boron Min	Boron Max	Boron Median	Boron Sufficiency range
Cranberry	4	171	24	15 - 30	2.3	188	52.0	15 - 60
Apple	6	261	19	25 - 35	0.2	69	32.0	30 - 40
Field corn	10	109	25	19 - 34	0.2	223	11.0	6 - 13
Field corn	11	132	29	20 - 60	0.1	99	8.0	5 - 25
Alfalfa	14	129	29	20 - 60	0.1	103	39.0	25 - 60
Soybean	11	795	43	25 - 88	0.2	116	37.4	27 - 224
Field corn	11	222	29	15 - 60	0.1	108	13.8	4 - 25
Grape	13	132	62	30 - 50	0.2	52	37.1	25 - 50
Strawberry	8	28	17	25 - 35	0.1	245	34.0	30 - 40
Blueberry	6	21	11	9 - 30	18.8	68	46.5	25 - 70
Cherry	10	21	14	25 - 35	24.4	254	37.8	30 - 40

Table 6.

Crop	Manganese Min	Manganese Max	Manganese Median	Manganese Sufficiency range	Iron Min	Iron Max	Iron Median	Iron Sufficiency range
Cranberry	19	1173	279	10 - 200	2	2486	83	20 - 300
Apple	8	353	41	30 - 50	2	766	49	90 - 120
Field corn	5	576	51	19 - 68	30	614	92	21 - 170
Field corn	6	1368	67	20 - 300	55	5933	244	50 - 250
Alfalfa	4	1781	42	20 - 100	34	1965	86	30 - 250
Soybean	2	3601	63	54 - 300	53	1429	135	50 - 300
Field corn	6	297	52	15 - 300	18	1643	109	10 - 200
Grape	10	577	95	30 - 1000	16	332	25	30 - 100
Strawberry	28	239	63	30 - 50	22	1112	118	90 - 120
Blueberry	90	812	365	50 - 60	41	99	62	70 - 200
Cherry	9	48	19	30 - 50	42	95	58	90 - 120

Table 7.

Crop	Copper Min	Copper Max	Copper Median	Copper Sufficiency range
Cranberry	0.6	495	3.9	4 - 10
Apple	3.4	218	6.2	7 - 10
Field corn	0.7	92	8.9	3 - 7.5
Field corn	2.0	182	7.0	5 - 20
Alfalfa	3.0	20.0	8.0	3 - 30
Soybean	1.7	16.0	8.8	6 - 15
Field corn	1.8	76.3	8.9	3 - 15
Grape	3.8	15.0	6.7	5 - 15
Strawberry	2.8	8.1	5.0	7 - 10
Blueberry	1.8	7.9	4.0	5 - 10
Cherry	5.3	10.0	7.0	7 - 10

2006 WISCONSIN CROP DISEASE SURVEY

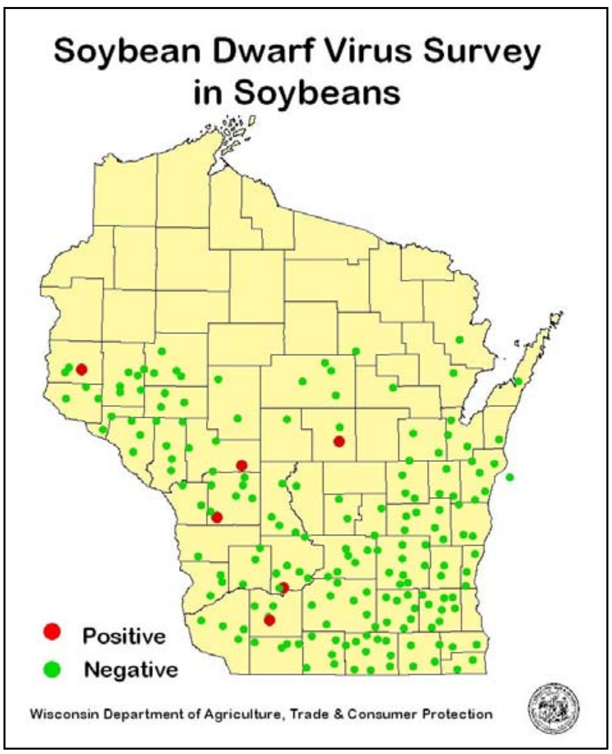
Anette Phibbs [1] and Adrian Barta [2]

The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) conducts pest and disease surveys to facilitate trade by documenting the absence of certain regulated diseases and pests in the state, by certifying crops for export, documenting known regulated diseases and detecting new and exotic diseases before they become a problem. For weekly pest and disease survey updates during the growing season please see the Wisconsin Pest Bulletin at http://pestbulletin.wi.gov/. Below are the highlights of the 2006 crop disease survey conducted by the Pest Survey Section:

Soybean Viruses & Asian Soybean Rust – Soybean dwarf virus but no rust.
Snap Bean Virus – No viruses detected.
Seed Corn – Stewart's wilt in one county.
Soybean Cyst Nematode – Spreading north!
Potato Cyst Nematode and Exotic Root Knot Nematode Survey – Clean fields in 2006!

Soybean Virus and Asian Soybean Rust Survey

The introduction of soybean aphids raised concern about aphid-vectored viruses such as the potyviruses: bean common mosaic virus, bean yellow mosaic virus and soybean mosaic virus (SMV). For the last four years, from late July to early August (R2 to R4 growth stage), soybean fields throughout the state were sampled randomly and tested for several viruses including bean leaf beetle-vectored bean pod mottle virus (BPMV) and thrips-vectored tobacco streak virus (TSV). Soybean fields were also scouted for Asian soybean rust (*Phakopsora pachyrhizi*). No Asian soybean rust was observed in any of the 188 fields visited in 2006 in Wisconsin. Foliar samples from each field were tested at Plant Industry Lab using DAS ELISA (double antibody sandwich enzyme-linked immunosorbent assay). All samples tested negative for BPMV, TSV and viruses in the potyvirus group. Six fields tested positive for soybean dwarf virus (SbDV), which was found for the first time in soybeans in Wisconsin in 2003. The low incidence of SbDV is consistent with previous years' survey results. ELISA positive SBDV samples were confirmed by molecular method (RT-PCR). Overwintering bean leaf beetles were tested for BPMV in April and May with beetles from three out of 81 alfalfa fields (the beetle habitat before soybean emergence) positive for BPMV.



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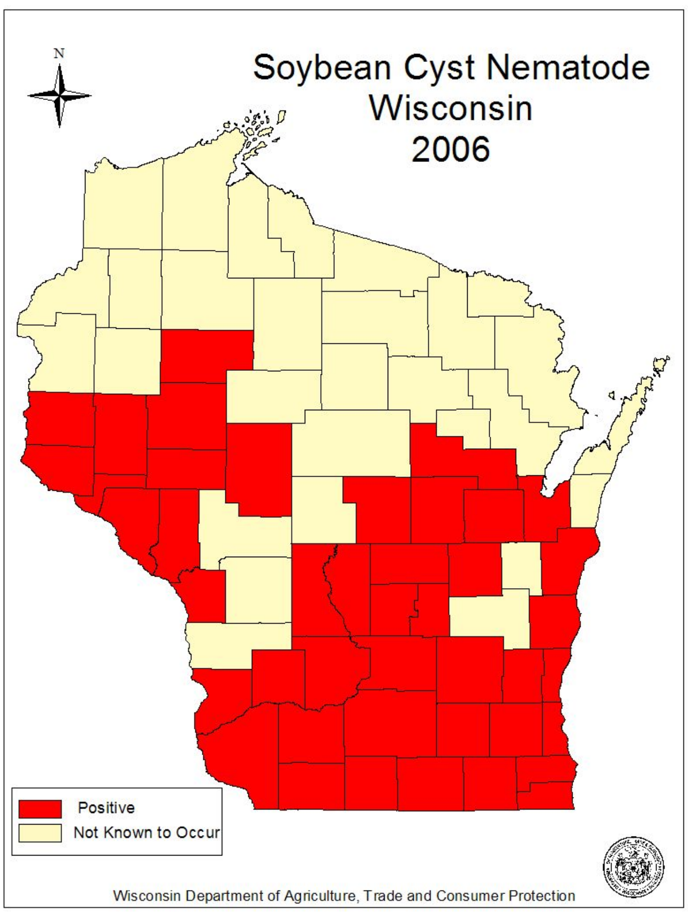
Snap Bean Virus Survey

According to the Wisconsin Agricultural Statistical Service, Wisconsin is the nation's top producer of snap beans. In 2006 snap bean fields in the northwest, north-central and north-eastern part of Wisconsin (Adams, Barron, Chippewa, Langlade, Marathon, Oconto, Portage and Waushara counties) were sampled and tested for four viral diseases. None of the 62 snap bean fields tested positive for BPMV, Cucumber mosaic virus (CMV), potyviruses or TSV.

Seed Corn Survey

In 2006, 53 seed corn fields were inspected for export certification. Foliar samples were tested for Stewart's wilt (*Pantoea stewartii*) and three viruses. Stewart's wilt infected seed is prohibited from export by 23 countries worldwide. *P. stewartii* is vectored by the corn flea beetle (*Chaetocnema pulicaria*), which is also the wintering reservoir. Flea beetles caught in 40 corn fields in spring did not carry the disease. This bacterial disease affects susceptible sweet corn varieties and inbred lines, most hybrid corn is resistant. In 2006 the disease was found in three fields in Grant County. Stewart's wilt has been documented in various locations throughout the state over the last 7 years. To meet the import requirements of foreign trading partners, all samples were also tested for three viruses: High plains virus (HPV), maize dwarf mosaic virus (MDMV) and wheat streak mosaic virus (WSMV). HPV, WSMV and their vector the wheat leaf curl mite (*Aceria tosichella*) are not known to occur in Wisconsin. No HPV or WSMV were detected. Four fields in Dane Co. tested positive for MDMV, which can be transmitted by more than 20 species of aphids.

Soybean Cyst Nematode Survey



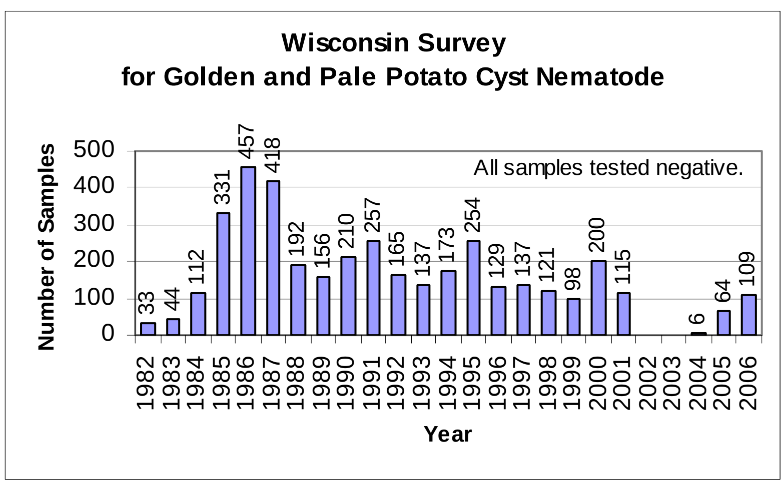
Soybean cyst nematode (*Heterodera glycines*), SCN, is the number one economic pest problem in soybean production in the U.S. causing an estimated $800 million to $1 billion in losses according to the American Phytopathological Society. Yield losses in Wisconsin were estimated at 1.9 million bushels in 2004. SCN was first detected in Racine County in Wisconsin in 1981. Soybean fields have been surveyed and field soils screened annually ever since. By 2006, 43 Wisconsin counties were known to be infested with SCN. The current map is based on cumulative data collected by WDATCP and the University of Wisconsin. For information about soil testing and SCN management please check the following websites http://planthealth.info/scnguide/ and http://www.plantpath.wisc.edu/soyhealth/index.htm.

Golden Nematode and Pale Potato Cyst Nematode Survey

On April 19, 2006, officials of the US Department of Agriculture's Animal and Plant Health Protection Service-Plant Protection and Quarantine (USDA APHIS PPQ) and the Idaho State Department of Agriculture (ISDA) announced the detection of potato cyst nematode (*Globodera pallida*), also known as pale cyst nematode (PCN) a major pest of potato crops previously not known to occur in the United States. Since the original detection, thousands of soil samples have been collected and screened by state and federal officials in Idaho. So far PCN has been detected in seven Idaho fields within close proximity. No seed production operations have been found to be infested with PCN.

PCN is widespread in Europe and South America. In North America, it had previously been detected only in Newfoundland, Canada. The nematode has the potential to cause crop losses up to 80% if populations reach critical levels. It affects potatoes, eggplant and tomatoes. Potato cyst nematode is closely related to golden nematode (*Globodera rostochiensis*, GN), an economically significant potato pest in Europe and a quarantine pest in many potato growing countries. Both nematode species form cysts on the true roots of potatoes. Laboratory diagnostics are required to differentiate one species from the other. Golden nematode was first discovered in the U.S. in 1941 in New York. It has been confined to New York by an effective state-federal quarantine for over 50 years. In Canada GN was known to occur only in limited areas in British Columbia and Newfoundland until on August 15, 2006, the Canadian Food Inspection Agency (CFIA) announced the detection of golden nematode in a commercial potato field near Montreal, Québec.

Neither the pale cyst nematode nor the golden nematode has ever been detected in Wisconsin. DATCP's Pest Survey and Control Section, participating with the USDA's Cooperative Agricultural Pest Survey (CAPS) program, has been sampling Wisconsin potato fields periodically for cyst nematodes since 1982. DATCP results for 2006 showed no evidence of either cyst nematode in 109 tested fields.



Currently USDA APHIS PPQ is formulating a survey plan that will be the standard for a nationwide survey. The draft survey plan requires sampling 100% of certified seed potato fields and 10% of each state's commercial potato fields. According to the Wis. Agricultural Statistical Service, Wisconsin growers produced 68,000 acres of potatoes in 2005, making the Badger State the fourth largest potato producing state in the nation. The state is also a leading seed producer, with 8,500 acres of seed production in 2006. DATCP is consulting with UW-Madison potato experts, the UW seed potato program and industry representatives to prepare for this survey. If implemented as currently proposed, the national survey may require a tremendous increase in sampling and screening capacity for DATCP.

Exotic Root Knot Nematode Survey

In 2005, Plant Industry Bureau staff has started a USDA CAPS funded survey for Columbia root-knot nematode (*Meloidogyne chitwoodi*) and False Columbia root-knot nematode (*M. fallax*). These microscopic worm-like pests are closely related to northern root-knot nematode (*M. hapla)* which is present in Wisconsin and feeds on a long list of vegetables and weeds including potatoes. Columbia root knot nematode (CRN) is a regulated pest of potatoes and common in the western part of the US but has not been found in Wisconsin. The closely related False Columbia root-knot nematode (FCRN) is not known to occur in the United States. Soil samples from 173 fields in 16 potato growing counties were sampled and screened for vermiform juvenile root-knot nematodes. Testing combined classic nematology methods and molecular techniques. Root-knot nematodes are separated from soil by Baermann funnel. The resulting nematode containing effluent is subjected to real time polymerase chain reaction (PCR). Plant Industry lab adapted PCR techniques that allow for the detection and positive identification of a single nematode in a sample which would be very time consuming to achieve using classic methods alone. All soil samples from Wisconsin potato fields tested negative for Columbia root-knot nematode and False root-knot nematode. The testing did reveal several fields infested with northern root–knot nematode (*M. hapla*). This survey will continue in 2007. Both potato cyst-and exotic root-knot nematode surveys are conducted to demonstrate to our trading partners that these pests are either absent from this state, or in the event of detection, provide growers with an early warning that allows for the greatest variety of response options including eradication.

For more information, please contact Anette Phibbs, DATCP, Plant Industry Laboratory, 4702 University Ave, Madison WI 53702. Phone (608) 266-7132 or email anette.phibbs@datcp.state.wi.us.

MANAGING CORN DISEASES IN CONTINUOUS NO TILL

Wayne L. Pedersen [1]

Introduction

Ethanol has dramatically increased the demand and the price of corn in 2006. This has resulted in an expected increased corn acres with fewer alternative crops in the rotation. In many cases the most profitable rotation is continuous corn. In addition, the increased fuel costs and improvements in machinery, seed, and seed treatments have encouraged a shift to reduced tillage, including no-till. Both continuous corn and no-till can have dramatic effect on plant diseases.

No-till soils tend to be cooler and wetter at planting and Pythium seedling decay and root rot can become a major factor. Pythium seedling decay and root rot is caused by an Oomycete (closely related to brown algae) and is considered a "killer" that can reduce plant populations substantially. Unlike soybeans that can compensate for missing plants, corn yields are dependant upon uniform populations. In continuous no-till corn, two other soil-borne diseases flourish. They are Fusarium root rot and Rhizoctonia root rot, which are considered "nibblers", because they generally reduce the root mass, especially the small fine roots. When plants are under moisture stress, they lack of these root hairs reduce the plants ability to extract water from the soil and can reduce yields without killing the plant.

In addition to soil-borne diseases, foliar diseases, e.g. gray leaf spot, northern leaf blight, southern leaf blight and eyespot increase in continuous no-till corn. The plant debris remaining from the previous crop provides a source of inoculum for the foliar diseases and the no-till environment keeps the debris cool and moist, favoring fungal sporulation. The main way to control these diseases has been through genetic resistance, crop rotation, and minimum tillage. However, under high disease pressure, many hybrids still suffer some yield loss due to foliar diseases. Foliar fungicides, Tilt and Quilt, have been used on hybrid corn seed production for many years, primarily due to the high value of the crop, but hybrid corn has had little use. With the increased price and demand, growers are asking if foliar fungicides, especially strobularins and triazoles, are profitable.

Results and Discussion

Foliar fungicides did increase yields in many cases, but not in all hybrids or at all locations. For hybrids that do not have a strong resistance package, they may be profitable. However, if hybrids with high yield and a high level of resistance are available, the yield increases many not be profitable. In addition, there are numerous claims that the strobularins group of fungicides promotes better health. They definitely affect some metabolic pathways and may affect yields in the absence of disease. However, there are few published reports detailing how this may work and under what specific conditions. As a plant pathologist, I prefer to focus on the control of plant diseases rather than a plant growth response. My only caution is to use only those adjavants recommended by the fungicide manufacturer and to apply the fungicide at the correct time, e.g. tassel emergence with the appropriate amount of water, pressure and droplet size.

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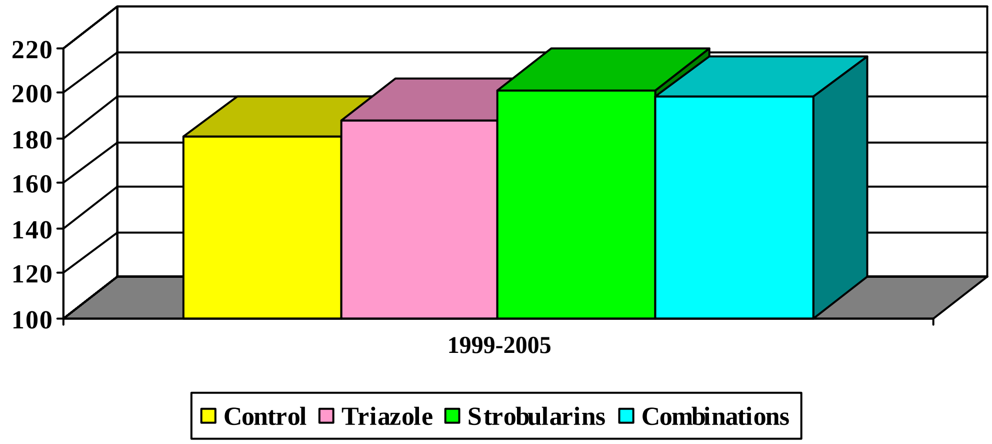

Figure 1. A summary of corn yields (bu/a) from plots treated with triazole, strobularins or combination fungicides at tassel emergence in Southern Illinois from 1999-2005.

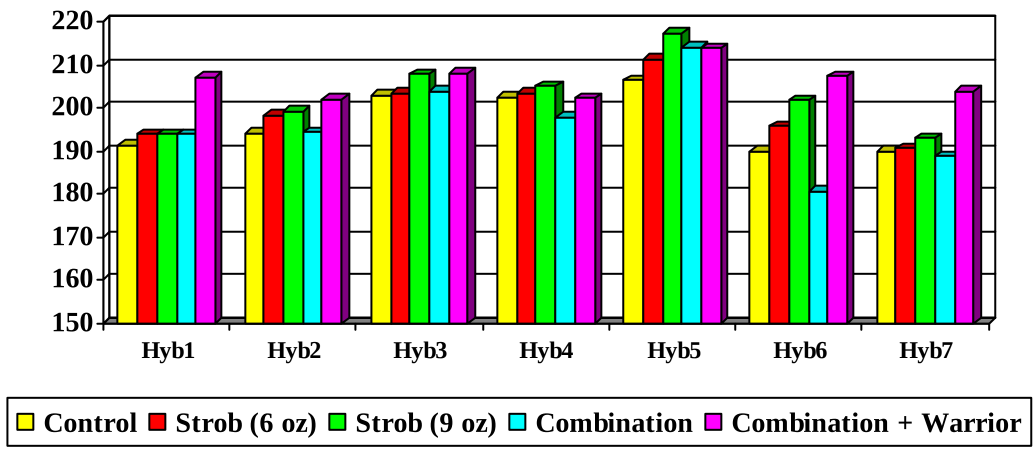

Figure 2. A summary of corn yields (bu/a) from ten hybrids treated with a strobularin fungicide, a combinations of strobularin and triazole, and the combination plus the insecticide Warrior in trials at University of Illinois South Farms, Urbana, IL in 2006

ARE SOYBEAN LEAF DISEASES CAUSING ECONOMIC YIELD LOSS IN WISCONSIN?

Craig Grau[1], Bryan Jensen[2], and John Gaska [3]

Introduction

The impact of foliar soybean diseases and the use of fungicides for both disease control and plant health benefits has become a focal point in soybean production since the discovery of soybean rust in the United States. As a result, the University of Wisconsin has initiated a two year research project focusing on foliar fungicide use in small research plots and large on-farm field plots.

On-Farm Field Trial Results

Nine trials were conducted in 2005 and six trials in 2006 using Headline applied at 6 oz./a during late R2 or R3 growth stage (2005) and R3 stage (2006). During the 2005 and 2006 growing seasons, a statistically significant yield advantage (P=0.05) of 1.4 and 2.8 bu/a, respectively, was observed in the Headline treated plots when yield data was combined across all locations for each year. Using current pricing scenarios (Table 1), we have calculated 3.4 bu/a as a baseline needed for an economic response to the application of a fungicide, ($7.50/a application fee and $6.00/bu soybean). Therefore, these yield advantages are not considered to be an economic benefit to the grower.

Table 1. Estimated yield gain needed to cover the cost of Headline ($270/gallon at 6 fl oz/a) at various soybean prices and application costs

	Application costs ($/a)		
Soybean price/bu	7.00	7.50	8.00
	---------------------------- bu/a --------------------		
$5.75	3.4	3.5	3.6
$6.00	3.3	3.4	3.5
$6.25	3.1	3.2	3.3

Of the nine individual field trials conducted in 2005, there was no statistical yield difference between treated and untreated plots within individual fields. In 2006, there was a statistically significant and economic yield advantage of 6.3 bu/a and 5.1 bu/a for each of two soybean varieties (maturity groups 1.5 and 0.8, respectively) at the Marshfield Agricultural Research Station and a 5.7 bu/a advantage using Headline in a Green County experiment. A statistical yield advantage was not observed for the four plots in Columbia, Dane, Green, and Walworth counties during 2006.

During the 2006 growing season, Bill Halfman and Steve Huntzicker, UWEX Monroe and La Crosse counties, respectively, initiated five on-farm plots using Quadris fungicide (6.0 fl oz/a) applied at growth stage R3. Pooled yield results from all locations did not indicate a statistical

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yield advantage to using Quadris. Yield results from individual fields indicated that only one of the five fields had a significant, but non-economic yield benefit of 2.0 bu/a.

Small Plot Research Results

Small plot research trials were also conducted in 2005 and 2006 using various application timings (R2, R3, R2+R3) of Headline + Folicur, Quilt, Laredo, and Punch. These products were chosen to represent different combinations of active ingredients and fungicide classes. Punch and Quilt are not registered for use on soybeans. Headline + Folicur and Laredo are approved for soybean rust only through the section 18 process and are not legal to use for other soybean disease or for plant health purposes. Results of this 2-year study at three locations (Arlington, Lancaster and West Madison Research Stations) indicate that fungicide treatments did not consistently increase soybean yields. Only one treatment, Punch applied at R3, increased yield enough to be statistically significant and economically feasible at the West Madison Station during the 2006 season.

Discussion

We have not identified a single key factor that would predict whether a fungicide application would result in an economic return. There is a trend for greater yield increases if fungicides are applied at the R3 growth stage when compared to applications at earlier growth stages. Weather conditions are a significant factor that contribute to disease development and thus, the yield response of soybean to fungicides. Soybean variety is another variable suspected to influence the response of soybean to fungicides. Results from Wisconsin and other Midwestern states suggest similar results. Funding for soybean fungicide research has been provided by the Wisconsin Soybean Marketing Board and participating companies.

Acknowledgments

Results used in this article would not be possible without the combined teamwork of several growers as well as the following UW and UW-Extension collaborators:

- Paul Kivlin, Richard Proost, and Karen Talarczyk, Nutrient and Pest Management Program;
- Bill Halfman and Steve Huntzicker UW-Extension;
- Mike Bertram, Marshfield Agricultural Research Station.

GROWER PERCEPTIONS OF TWOSPOTTED SPIDER MITE CONTROL

Greg Andrews[1] and Lee Milligan[2]

Introduction

In 2006, like other regions of Wisconsin in previous years of low moisture to drought conditions, saw significant increases in twospotted spider mite, (TSM) infestations. Lessons learned from these other regions and previous outbreaks in 1983, 1988, 1995, and 2005, indicated that soybean damage could be anticipated. Research trials for developing Integrated Pest Management (IPM) recommendations are difficult. Further, specific economic thresholds do not exist for twospotted spider mite in soybeans (Cullen, 2006).

Northwestern Wisconsin observed moderate to severe drought conditions in 2006. In Northern St. Croix County, WI, soil moisture conditions were described as severe from May through Early August. Moisture stress for soybean was also severe and the conditions were right for TSM populations to increase to damaging levels. Crop consultants, dealers and UW-Extension agriculture agents in Northwest Wisconsin reported early observations in mid-July. Peak reports of damage occurred during the first week of August. Evaluating grower perceptions when TSM infestations occur, studying grower decisions and connecting grower decisions to observed outcomes of their decisions is core to this study. The study is both quantitative and qualitative and is based upon the 2006 UW-Extension Grower Survey on Twospotted Spider Mite in St. Croix County, Wisconsin.

Twospotted Spider Mite Abbreviated Review

TSM are very small and are difficult to see with the naked eye. Their small size (one to two-tenths of an inch) typically requires the scouts and growers to use the aid of a hand lens. Detection of TSM can be overlooked. TSM have long pointed mouthparts that extract nutrients from individual leaf cells. The extraction of cell contents leads to the depletion of chlorophyll content in cells. As the cell content depletion escalates, the presence of small oval white or yellow specks becomes more apparent. These symptoms are know stippling and are usually first observed on the undersides of leaves. As more feeding occurs under moisture stress conditions, data suggests potential yield reductions of 40 to 60% (Klubertanz, 1994).

Scouting and monitoring of TSM in soybean should begin at the field edges and borders. The presence of TSM does not predict that spread of this pest further into the interior of fields. However, the monitoring of the entire field is recommended, especially if moisture stress conditions continue. Stippling of soybean leaves is indicative of TSM feeding. The full range of the leaf canopy should be observed. Tapping the soybean leaves to dislodge TSM over a white sheet of paper is an accepted practice to check for the presence of TSM.

The primary natural enemy TSM is the fungal pathogen *Neozygites floridana.* This host specific pathogen infects TSM under environmental conditions that are cooler than 85^{o}F and with at least 90% humidity lasting 12 to 24 hours. Under these conditions and once infection occurs, death of TSM usually occurs within 1 to 3 days (Cullen, 2006).

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Grower Perceptions

For soybean growers in St. Croix County, 2006 was likely the first year that TSM was a serious management challenge and economic threat. Following the soybean harvest in 2006, a grower survey was completed. The first reported observations of TSM occurred on July 15 and the latest first observation by growers was on August 8. Nearly half of the growers surveyed learned about TSM at the Pierce/St. Croix Soybean Diagnostic Field Day on August 2, and subsequently found TSM in their soybean fields later that day or in the days following. It should be noted that Dr. Eileen Cullen identified and demonstrated TSM scouting awareness for the growers.

The majority of growers (76%) reported that actual detection of TSM populations was the primary determination for recognizing that an infestation and damage potential existed. Growers also reported that the observation of TSM damage (stippling, yellowing, and bronzing) influenced how they recognized the problem. Growers credited independent crop consultants, dealer agronomists, UW-Extension agents and themselves in near equal proportion for the scouting or the training necessary for scouting. While not asked in the grower survey, it can be inferred that considerable networking and sharing of information among growers, UW-Extension agents and agronomy professionals was key to grower's capacity to deal with the TSM infestations in the region.

Understanding the management decisions made by growers was integral to the grower survey. The length of time between first observing TSM in soybean and the time when applications were made varied from 1 to 15 days. While this may not seem significant it could suggest that growers continued to scout and monitor fields and base their application timing according to the severity of the infestation. The majority of growers made decisions on a field by field basis. Portions and perimeters of fields were sprayed. In only one case did a grower spray all of the field area in all of the fields. Again, this reaffirms that growers were making evidence-based decisions with professional advisors. The majority (68%) of the treatment recommendations were made by dealer agronomists. Treatment recommendations by Independent Crop Consultants, UW-Extension, and fellow producers were followed by (32%) of the growers. Costs for treatment of TSM varied from $4.50 to $13.50 per acre. Some included custom application costs while others did not.

A post-harvest survey measured grower estimates for soybean yield on treated and non-treated locations. Nearly three-fourths (73%) of the growers felt that treatment for TSM reduced yield losses. Some growers reported mixed results. Reported yield saved ranged from 2 to 10 bushels and the average response was 6 bushel per acre. However, growers were also asked if they saw a "marked difference" between treated and untreated acres. Only half of the growers responded yes. Qualitative comments by growers ranged from "Didn't have to spray some fields because I watched them closely", to "Better color....more growth....better yield". Based on grower perceptions, TSM is a soybean pest with little predictability other than scouting soybeans routinely. Continue to scout for TSM throughout the growing season recognizing that economic thresholds are not yet determined but are a priority for ongoing research. Experimental designs for establishing economic thresholds are difficult because moisture stress and drought are associated factors with TSM damage. Growers and agronomy professionals need to keep this pest on their scouting list throughout the growing season.

References

Cullen, E.M. 2006. Spider mites from A to Z. Proc. 2006 Wis. Fert., Aglime, and Pest Mgmt. Conf. 45:130-133.

Cullen, E.M. 2006. Twospotted spider mite persists in northwestern Wisconsin. Wis. Crop Mgr. 13(23), August 17, 2006 WWW document URL http://ipcm.wisc.edu/wcm/insects.html

Klubertanz, T.H. 1994. Twospotted spider mite. p. 92-95. In L.G. Higley and D.J. Boethel (ed.) Handbook for soybean insect pests. Entomol. Soc. Am., Lanham, MD.

WESTERN BEAN CUTWORM IN CORN

Eileen Cullen [1/]

{This page provided for note taking}

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MANAGING DRY GRAIN IN STORAGE [1/]

Scott Sanford [2/]

A great deal of resources and effort are invested in growing, harvesting, drying and transporting grain crops. Managing the dry grain in storage is important to protect that investment. The quality of grain cannot be improved during storage but if not properly managed, grain quality can deteriorate quickly. The majority of grain losses are caused by living things such as fungi, mold, insects and rodents. The grain temperature and moisture can provide a haven for living things or aid in preventing problems.

There are six main causes of grain storage problems: grain is too warm, grain is too wet, too much foreign matter and fines, uneven grain temperatures in bin, storage bins not cleaned before harvest, and grain not checked often enough during storage.

Grain that is too warm and too wet invite molds and insects, the primary reasons for grain deterioration in the U.S. Insects and molds thrive in temperatures above 60°F. Molds are more predominate if grain moisture is too high while insects can survive in dry or moist conditions. Insect damage and mold will often occur in areas of high foreign matter and fines because it is often higher in moisture and broken kernels are easy access. Too much foreign matter and fines also causes higher resistance to airflow compounding the problem of aerating the grain. Screening all grain before it enters the storage bin and the use of a spreader to evenly distribute the grain and fines in the bin will reduce concentrated areas of fines. If not using a spreader, fines and foreign matter will concentrate under the fill spout.

Differences in air temperature within a grain bin can lead to convection patterns within the grain. The grain near the wall of the bin will be cooler while the grain in the center of the bin will be warmer. The warm air will migrate up through the grain in the center of the bin, picking up moisture until it comes in contact with the cold grain on the top where the moisture condenses on the cold grain and the bin roof. The wetted corn will be prone to mold growth and insects as the sun heats the roof and head space as the weather warms in the spring. Crusting of grain is an indication of convection air movement and uneven grain temperatures. It is recommended that the grain temperature be kept within 10 to 15°F of the average outdoor temperatures down to 30-35°F for southern WI, Iowa, Michigan and Northern IL and 25 to 30°F for northern WI, Minnesota and the Dakotas. During the warmer months the grain temperatures should be kept slightly lower than the average temperature. The maximum recommended summer temperature of the grain is 50°F for the upper Midwest. Keep the grain temperatures within will reduce 10 to 15°F of the average outdoor temperatures will reduce convection air flow in the grain.

Bins that were not cleaned out from the previous year are more likely to have insect infestations from adult insects, larvae and eggs that are harbored in the old grain. Cleaning bins is effective for insect control but has little effect on molds. The best strategy mold control is to prevent mold spores from germinating by keeping the grain cool, clean and dry. Trapping insects to determine infestation level should be done for grain that is stored during warm weather. Sticky traps, probe traps, and pitfall traps are useful in determining infestation levels. Check with buyers of grain before applying any insecticides to ensure you are not jeopardizing your market.

[1/] Funded in part by the Wis. Focus on Energy Program.

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Neglect or irregular visits to grain bins or storage facilities can result in a small problem, which could have been controlled, turning into a large costly problem. It is recommended that grain be checked every one to two weeks in warm weather and every two to four weeks in cold weather.

During inspections check that bin hatches are closed and not leaking water, roofs are not damaged, roof vents and fan inlets are not blocked by frost, ice or debris, fans are operable (tripped breakers, burned out motors, damaged bearings or impellers), and controllers are operational. What does the grain smell like - musty or spoiled odor? Hard crust on surface, condensation under the roof, exhaust air temperatures warmer in center than those away from the center, these are all indicators of storage problems. Make a log of your observations for future reference. The storage moisture of the grain will depend on how long it is planned to be in storage, the grain crop and the type of storage facility. It may be desirable to reduce the moisture content of crops stored in a temporary storage structure by a percentage point or two to reduce the spoilage risk because of less than ideal conditions.

Aeration

It is not critical for maintaining grain quality in storage whether the aeration system is a positive or negative pressure system, there are advantages and disadvantages of both. The airflow per bushel is more critical because it affects the time required to change the grain temperature. A bin with 0.10 cfm per bushel airflow rate will require approximately 140 hours (6 days) to change the grain temperature of corn 10 to 15°F while an airflow rate of 0.25 cfm per bushel will require only 56 hours (2-1/3 days), 2.5 times less time. Higher flow rates allow operator to take advantage of short periods of cool weather (nights, cold fronts) during the warmer parts of the harvest season to cool the grain and provides more accurate temperature control. But as airflow rate doubles, the horsepower requirement will increases by a factor of about five and will require larger electrical services. Aeration times will depend on how uniform air flows through the grain; areas of concentrated fines may require 2 to 5 times longer to cool than if grain were clean. Operators often try to avoid aeration during very high or low humidity conditions but this will only have a slight effect on the grain at the point were the air enters the bin because temperature of grain changes about 50 times faster than its moisture content changes. It is important to turn off the aeration fans as soon as the grain reaches the target temperature so drying or wetting of the grain is minimized.

Temperature Sensors

The only way to determine if grain cooling is complete is to take temperature measurements of the grain in several locations. This can be accomplished with a grain probe with a thermometer pushed into the grain or by pulling a grain sample and measuring the temperature quickly to determine grain temperature at various locations and depths. Permanently installed vertical temperature cables can also be used. These cables have temperature sensors every 4 to 6 feet along the length to measure grain temperatures. This data is useful if it is recorded regularly and compared to previous readings to detect temperature increase or decreases at sensor locations. Sensors can only accurately measure the grain temperature within a few feet of the sensor so they should be considered an aid but not a substitute for measuring temperatures in other locations. Small temperature increases in one area can be an indication of problems.

Controls

Fans can be controlled manually, with time clocks, thermostats, microprocessor based controller or computer-based software. Automatic controls can reduce time and energy required to manage stored grain and improve the accuracy. If using a simple thermostatic controller, an hour meter should be installed so the number of hours the fans operate is known. Automated controllers do not eliminate the need to visually check the grain.

Safety

Every year people are injured or killed in association with grain handling and storage. DO NOT ENTER BINS WITH UNLOADING EQUIPMENT OPERATING! Even a low capacity auger can bury a person in seconds. Don't walk on crusted grain if grain has been removed from bin. A cavity can form under the crust which may collapse when walked on, burying the person. Lock-out controls if entering a bin so unloading equipment can't be started. Wear respirators when working with moldy grains. Be aware of overhead electrical lines when moving equipment or lifting dump bodies.

Monthly Monitoring Checklist

1) Turn on aeration fans
    a. Is fan operating correctly? Inlet clear, bearing, fuses
    b. Check Static pressure in plenum
2) Climb up and look inside bin
    a. Condensation under roof, wet grain near hatches
    b. Snow cover – run fans until sublimated
    c. Check for off-odors
    d. Check grain surface – crusting, mold, wet spots (roof leaks?)
    e. Measure grain temperatures at several locations and depths
3) Check for signs of insect, mold and rodent activity
4) Record observations in logbook
5) Compare observations with previous records
6) Take any corrective action required

References

Reed, Carl, "U.S. Corn – Storage in Tropical Climates", U.S. Grains Council, Washington DC., available at www.grains.org/galleries/technical_publications/SorgEng.pdf.

"Stored Grain Management: Storing Grain in Bins", Chapter 10, Agronomy Guide for Field Crops, Ontario Ministry of Agriculture, Food and Rural Affairs, 2002. Available at www.omafra.gov.on.ca/english/crops/pub811/10bins.htm

Wilcke, B., K. Hellevang, J. Harner, D. Maier, B. Casady; "Managing Dry Grain in Storage", AED-20, Midwest Plan Service, Ames, IA, 2004. Available for ordering from www.mwps.org

CRITTERS IN THE BIN—WHAT NOW?

Phil Pellitteri [1/]

There are over 100 different insects and mites found infesting grain in Wisconsin. About 90% are small beetles while most of the remaining species are caterpillars and moths. These insects and mites can be divided into three general groups depending on the types of feeding, potential damage, and the environments they prefer. One of the major problems is that these insects look so similar, but control options will differ depending on what insect is associated with the stored grain. Not all infestations need to be fumigated or sprayed.

PRIMARY FEEDERS (Internal feeders) are those stored product pest which can feed on and breed inside whole, sound grain. There are only 6 to 8 species that are primary pests in the U.S. and only 3; the GRANARY WEEVIL, MAIZE WEEVIL, and occasionally LESSER GRAIN BORER are found in Wisconsin. At temperatures above 60°F these insects can go through a generation in 3 to 4 weeks and each female lay up to 300 to 400 eggs during her lifespan. Larvae develop within the grain kernels, completely destroying the interior, and leave behind a hollowed kernel. On a worldwide basis and in warmer areas in the southern U.S., primary feeders are the most serious stored grain pests. They will go through 12-generation/ year and can even infest grain in the field. In Wisconsin they are not very common, can only go through 3 to 4 generations per year and we DO NOT get infestations before harvest.

SECONDARY FEEDERS (**external feeders**) only feed and breed on broken kernels, fines and grain damaged by primary feeders. They can feed on milled and processed foods as readily as whole grain. There are about 30 common species statewide and are often called bran bugs. They include the red flour beetle, saw-toothed grain beetle, Indian meal moth and mealworms. Most species will to through one generation per month during summer conditions and populations can increase by 10 to 15 times per generation. High populations can become a significant problem and will feed on fines, and broken grain. Like the primary pest, they are not the most common group of insects found in Wisconsin stored grain.

INDIAN MEAL MOTH deserves special attention because it has become increasingly common in the past years and it shows moderate resistance to some treatments. The adult is a small tan moth and does not feed on grain. The larva is a yellowish caterpillar that feeds in the upper few inches of the grain mass and will web grain together. Crusting and webbing will often develop on surfaces. This prevents proper air movement and can lead to serious moisture problems. Infested bins can be fumigated or treated with any one of a number of insecticides (besides malathion) but the webbing, crusted, or spoiled grain must be removed before application.

FUNGUS FEEDERS are insects and mites found in stored grain that do not attack the grain, but feed on the mold and mildew associated with damp grain. Any grain above 15 to 20% moisture content is susceptible to being attacked. Many species are rusty red or brown beetles that look similar to the other stored product pests mentioned previously. Most fungus feeders can fly and are attracted in large numbers to musty smelling grain. A large population generates heat and will cause additional moisture to condense, more mold will grow and additional fungus feeders will be attracted to the site. A chemical treatment (fumigating and/or grain protectent) will kill these insects but if you do not

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correct the moisture problem new insects will begin to fly in almost immediately. The foreign grain beetle, flat and rusty grain beetles, the hairy fungus beetles and grain mites (Acarus) all belong to the fungus feeding group. Over 80% of the insect infested corn samples sent to the U. W. diagnostic lab contained fungus feeding insects as their major problem. These insects would not be present in properly handled low moisture grain. Control of these fungus feeders can be as simple as proper aeration.

Environmental Requirements

None of the insects that attack stored wheat, barely, oats and corn will develop at temperatures below 50^{o}F. Grain that is harvested and placed in a clean bin will be free of any insect problems until the following summer. Grain that is held at 12 to 13% moisture content will not become moldy and will not attract major insect problems.

Never place new grain on top of old grain. And remove residue from fans, rafters, floors, walls, and ducts. Grain that contains cracked kernels, weed seeds or other foreign material tends to become infested more readily than clean sound grain. Screening will help reduce many problems except the primary feeders. To prevent any increase in moisture content, all holes in the roof must be sealed and proper aeration techniques must be utilized.

Stored grain should be inspected every 2 to 4 weeks from May through October and monthly from November to April. Grain probes can be used, or specially designed probe traps will help monitor insect problems. When insects are found, you must determine whether or not the infestation warrants control. Get help in proper identification of the insects involved. It is very important to know what you have got to be able to predict potential damage and select the proper control.

Type of Treatments Available

Residual bin sprays are used on walls, ceilings, roof, and floors of clean bins prior to harvest. All debris should be swept up and all cracks and crevices sprayed with a residual insecticide. The area under perforated floors will need to be cleaned out or fumigated. Do not store livestock feed close to the grain bin as this is a source of insect infestations. Products registered for treatment of empty bins include Storcide II (chlorpyrifos-methyl + deltamethrin), Storcide (chlorpyrifos-methyl + cyfluthrin), Tempo (cyfluthrin), Malathion (not all labels), Reldan 4E (chlorpyrifos-methyl-discontinued)), Diacon II [(s)-methoprene], Silicon dioxide and/or diatomaceous earth (DE) (Insecto, Perma-Guard, and others), and Bacillus thuringiensis (Bt) (Dipel, Biobit- Indeain meal moth only.

A number of insecticides are labeled for use on stored grain. Depending on the situation and insect involved insecticides can be used as a surface treatment (for Indian meal moth) or applied uniformly as grain is being loaded or transferred. In most cases all grain will need to be treated. Treatment can put on as a protectent to prevent problems in storage. Read the label carefully as not all products are labeled for all grains. Products registered for this use include Actellic (pirimiphos-methyl), Storicide Dipel (for Indian meal moth) silcon dioxide/diatomacous earth and the growth regulator Diacon II and dust formulations of Malathion

Grain that is already infested can also be fumigated. All fumigants are extremely toxic and dangerous if improperly used. Recently the EPA revised fumigants regulations and proper use requires self-contained breathing apparatus and gas concentration monitoring equipment to use the fumigants according to label directions. Fumigants are tricky to use properly and their effectiveness is influenced by temperature, wind speed, bin size and grain being treated. There are also other regulations which must be followed for proper use. A commercial fumigator should be hired for treatments. They have the experience and the equipment to do the job properly.

There are three fumigants now being used for treating grain. Cloropicrin (tear gas) can only be used in empty bins. Because it is heavier than air it is used to control insects in subfloor areas. Phosphine is a solid fumigant that when exposed to moisture releases the toxic gas phosphine. The grain mass is often tarped after treatment and the bin is kept sealed for 2 to 8 days, depending on temperature. Methyl bromide is an odorless gas hat is highly effective on all life stages of insects, but it is likely to be banned in the next few years because of ozone depletion concerns. It is a restricted use product that is available only to professional fumigators. For proper use grain temperature must be at least 50^{o} and preferably above 60^{o}F for treatment with any fumigant.

MANURE PHOSPHORUS SOURCE AND RATE EFFECTS ON SOIL TEST LEVELS AND CORN GROWTH

Emily G. Sneller and Carrie A.M. Laboski [1/]

Introduction

Nutrient management planning has become an important tool in an effort to improve water quality. In Wisconsin, nutrient management regulations are in the process of moving to a phosphorus (P) based standard. As such, P budgeting and the P index will greatly influence manure applications. Thus, there is a need to better understand how soil test P changes with respect to P based manure application.

In Wisconsin, only 60% of the total P applied in manure is considered to be available to the crop during the first year after application (i.e. relative availability (RA) of 0.6). From a P budgeting standpoint, this means manure is 60% as effective at increasing soil test P as the same amount of total P applied as fertilizer.

Past research has shown that these assumptions are not always true. Studies have shown that manure phosphorus can vary from being more available to less available depending on animal species, manure type, and storage of the manure. Eghball et al. (2002) found that first year P availability of cattle feed lot manure was 85% in a field experiment. In a complimentary incubation study, beef cattle feedlot manure averaged 72% P availability compared to fertilizer while swine slurry averaged 66% P availability (Eghball et al., 2005). In an incubation study by Kashem et al. (2004), P amendments increased labile P levels to varying degrees with fertilizer increasing labile P the most followed by hog manure, cattle manure, and biosolids. In an incubation study Laboski and Lamb (2003) found that swine slurry applied at high rates increased soil test P more than fertilizer.

Most of the past research on manure P availability has been conducted in laboratory incubations. The purpose of this study was to determine manure P availability to corn on a total P applied basis, as compared to fertilizer in a field setting.

Materials and Methods

This study was conducted at the University of Wisconsin Agricultural Research Stations in Marshfield (central Wisconsin) and Arlington (south central Wisconsin). General characteristics for soil are provided in Table 1. The experimental design at these locations was a randomized complete block. Treatments consisted of five P sources at Arlington (fertilizer (0-46-0), dairy slurry, solid dairy manure, swine slurry, and poultry pellets) and four P sources at Marshfield (fertilizer, dairy slurry, solid dairy manure, and swine slurry) as well as a no P control for both locations. Table 2 contains characteristics of the manures used at both locations. Plot size was 10 by 30 feet.

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Table 1. Soil characteristics.

Location	Soil series	Taxonomic name	pH	P	K	Ca	Mg	OM
				——— ppm ———				%
Arlington	Plano silt loam	Fine-silty, mixed, superactive, mesic Typic Argiudolls	6.5	16.8	77.3	1784	535	3.7
Marshfield	Withee silt loam	Fine-loamy, mixed, superactive, frigid Aquic Glossudalfs	7.1	14.3	125.3	1441	433	2.7

Table 2. Manure characteristics.

Manure	Total N	NH_4-N	P	K	S	DM†
						%
Arlington						
Dairy slurry (lb/1000 gal)	34.25	14.89	5.27	20.10	1.64	10.3
Swine slurry (lb/1000 gal)	22.87	17.58	5.02	11.37	1.08	2.7
Dairy solid (lb/ton)	10.76	3.87	1.63	6.17	0.59	18.9
Poultry pellets (lb/ton)	70.55	8.82	33.9	42.53	3.85	84.0
Marshfield						
Dairy slurry (lb/1000 gal)	20.18	10.19	3.88	15.76	1.34	6.1
Swine slurry (lb/1000 gal)	25.2	17.56	4.72	10.37	1.02	2.8
Solid dairy manure (lb/ton)	9.46	2.68	1.67	10.44	2.68	19.9

†DM, dry matter.

Each P source was hand applied preplant at three target application rates of 80, 160, and 240 lb P_2O_5/a, or low, medium, and high rates. Total P in the manure was confirmed in the lab and actual P_2O_5 application rates calculated (Table 3). Manure credits for nitrogen (N), potassium (K), and sulfur (S), were taken and fertilizer was applied to all plots to meet total application rates of 200 lb N/a, 120 lb K_2O/a, and 15 lb S/a. Two days after treatment application, plots were chisel plowed to 8 in and the seed bed was prepared with a soil finisher. An adapted corn (*Zea mays)* hybrid was planted at each location.

Table 3. Amount of P applied for each P source and rate at Arlington and Marshfield.

Source	Phosphorus application rate Low	Medium	High
	——— lb P_2O_5 /a ———		
Arlington			
Fertilizer	83	166	248
Dairy slurry	76	152	227
Dairy solid	67	134	201
Swine slurry	62	125	187
Poultry pellets	77	154	230
Marshfield			
Fertilizer	83	166	248
Dairy slurry	57	114	171
Dairy	47	137	205
Swine slurry	59	117	176

Soil samples (0 to 6 inches) were taken in every plot prior to treatment application, 2, 4, and 10 weeks after application, and post harvest. Samples were dried and ground to pass a 2 mm sieve. Phosphorus was extracted with Bray-1 and analyzed colorimetrically (Frank et al., 1998).

Plant samples were taken throughout the growing season. Whole plant samples were taken at the V5 growth stage, ear leaf samples were taken at tasseling, and whole plant samples for silage yield were taken at physiological maturity. All plant samples were dried and ground to pass a 2 mm sieve and then digested (H_2SO_4 + H_2O_2) and analyzed colorimetrically for total P.

For each location, linear regression was used to model the relationship between the change in STP with P application for each P source and date of sampling. The slope of the regression line for each manure source on a given date and location was compared to the slope of the regression line for fertilizer on the same date and location. If the slopes were significantly different, then manure changed soil test P differently than fertilizer and the relative availability (RA) was calculated. Relative availability was calculated as the ratio of the slope of the regression line for manure to the slope of the regression line for fertilizer. Silage harvest P uptake for Arlington and Marshfield and silage yield at Marshfield were fit with a linear plateau model.

Results and Discussion

In general, as total P applied increased so did soil test P (STP) levels. However, different trends were evident between locations and sampling dates (Figure 1, Table 4). At Marshfield, fertilizer and swine slurry showed an immediate and similar increase in STP at the 2-week sampling date (Figure 1). Dairy slurry and solid dairy manure changed STP similarly and significantly less than fertilizer and swine slurry. At the post harvest sampling, all sources changed STP similarly with the change being less than at 2 weeks. At Arlington, fertilizer increased STP significantly more than all manures. By post harvest sampling, all sources changed STP similar to fertilizer and were not significantly different. At Arlington changes in STP at post harvest were less than at 2 weeks after application. The reduction in STP change at post harvest for both locations could be a result of P binding with soil over time or possibly from crop removal.

Table 4. Comparison of the ability of manure P to change STP similarly to fertilizer P.

	Arlington		Marshfield	
Source	Two week	Post harvest	Two week	Post harvest
	P value †			
Dairy slurry	0.0001	0.3127	0.0028	0.3687
Dairy solid	<0.0001	0.4405	0.0626	0.4728
Swine slurry	<0.0001	0.2935	0.7114	0.3106
Poultry pellets	<0.0001	0.6210	—	—

† H_o: slope of change in STP with manure P applied = slope of change in STP with fertilizer P applied.

Relative availabilities were calculated for the manure sources at the 2 week sampling date (Table 5). Manure sources behaved differently depending on location. At Marshfield, swine slurry was the only source that was as immediately available as fertilizer. The RA of dairy slurry was similar at Marshfield and Arlington, 0.22 and 0.19 respectively. Solid dairy manure had a

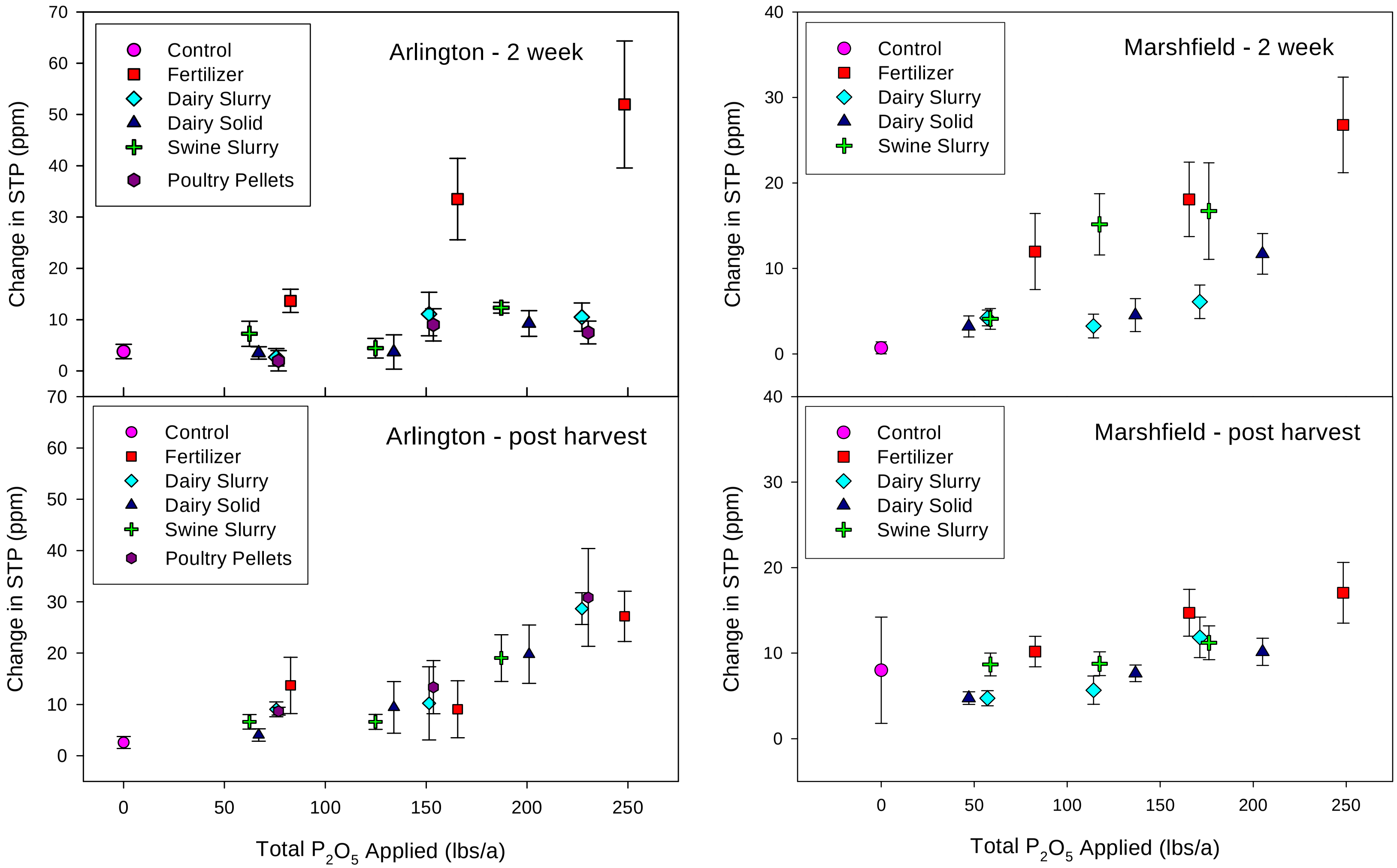

Figure 1. Change in STP with P_2O_5 applied for each P source at Arlington and Marshfield at the 2-week and post-harvest sampling date.

RA of 0.58 at Marshfield which was greater than 0.19 at Arlington. The range of RA's from the different manures was small at Arlington (0.16 to 0.22), whereas, at Marshfield the range was large (0.19 to 1.2) (Table 5). For the post harvest sampling, there was no significant difference between fertilizer and manure sources within a location, thus the RA for all manure sources was 1.00. The post-harvest results suggest that the current RA of 0.6 for manure the first year after application may be underestimating P availability to the crop, based on changes in STP, and may not be taking into consideration manure or soil type differences.

Table 5. Relative availability of manure sources at 2-week sampling date. †

	Relative availability	
Source	Arlington	Marshfield
Dairy slurry	0.22 ***	0.19 **
Dairy solid	0.19 ***	0.58 *
Swine slurry	0.16 ***	1.20 NS
Poultry pellets	0.18 ***	—

NS = not statistically significant
*Significant at the 0.1 probability level
**Significant at the 0.05 probability level
***Significant at the 0.001 probability level
† If relative availability (RA) = 1, then manure P is as available as fertilizer. If RA< 1 and is significant, then manure P is less available than fertilizer. If RA> 1 and is significant then manure P is more available than fertilizer.

At Marshfield a linear plateau model showed that P uptake increased as total P applied increased up to 123 lb P_2O_5/a for all sources and then plateaued (Figure 2). The high rate of solid dairy manure was removed from the data set before the model was fit because the large increase in uptake was caused by a large biomass yield. Greater biomass yield in the high rate of solid dairy manure is believed to result from a mulching effect of the solids (bedding, undigested feed, etc.) in the manure maintaining soil moisture. This was evidenced by the fact that the corn was slower to show signs of moisture stress during a period of dry weather. The relationship between total P_2O_5 applied and P uptake indicates that for corn, manure P is equally effective at supplying P as fertilizer. At Arlington, for all manure sources, P uptake increased as total P applied increased up to 168 lb P_2O_5/a. After this rate, P uptake leveled off. Fertilizer was not used in the linear plateau model because it appeared to follow a more linear trend and seemed to have reduced P uptake compared to manures; this relationship is being investigated further.

At Marshfield, silage yield response to applied P was fit to a linear plateau model (Figure 3). Again, data from the high rate of solid dairy manure were not used for the reason explained previously. Silage yield increased as total P applied increased up to 91 lb P_2O_5/a and then plateaued. Trends in silage yield were not as easily observed in the Arlington data (data not shown). At Arlington, it is believed that the variation in initial soil test levels within the field may have affected the P responsiveness. Additional statistical analysis is being conducted on this data.

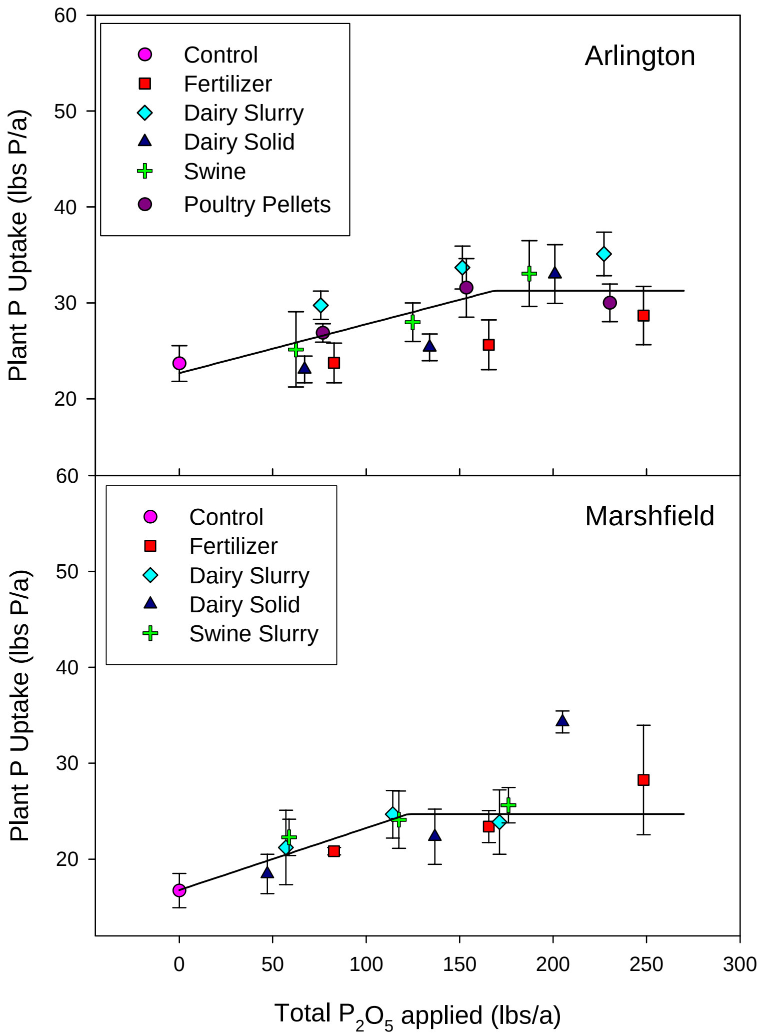

Figure 2. Relationship between plant uptake of phosphorus in silage and P_2O_5 applied for each P source at Arlington and Marshfield.

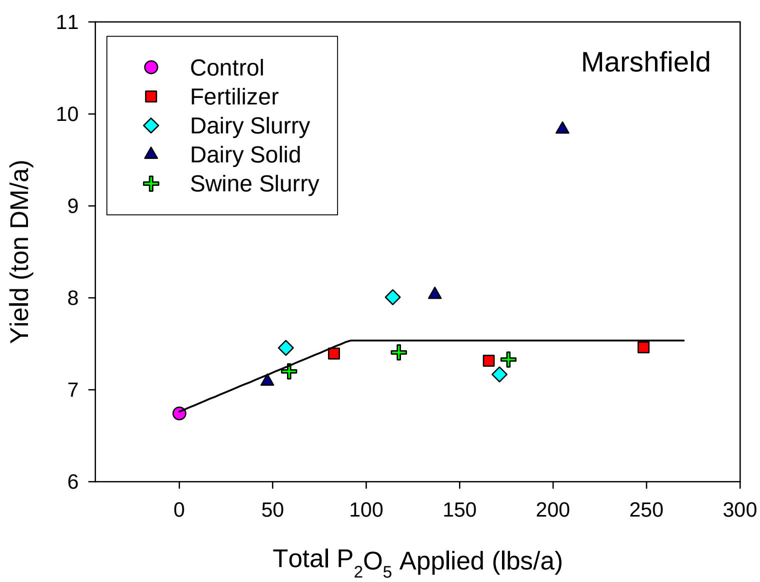

Figure 3. Relationship between silage yield and P_2O_5 applied for each source at Marshfield.

Conclusions

Differences between P sources in their ability to change STP were observed. Additionally, change in STP varied with soil and manure type. This implies that using a constant availability coefficient, such as 60% of total P applied, for all manures may not be the most effective way to account for manure P. Details of these relationships will be investigated further. From the P uptake and yield data, manures are equivalent sources of P for corn based on total P applied. Thus, manure P availability in terms of crop need appears to be 100%. Phosphorus availability in relation to how it changes STP may not be as important to determining crop response and growth but rather play an important role in addressing environmental concerns from P loss. Through further analysis and research, a better understanding of the differences between manure sources and soil types is hoped to be gained.

Acknowledgments

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References

Eghball, B., B.J. Wienhold, J.E. Gilley, and R.A. Eigenberg. 2002. Mineralization of manure nutrients. J. Soil Water Conserv. 57:470-473.

Eghball, B., B.J. Wienhold, B.L. Woodbury, and R.A. Eigenberg. 2005. Plant availability of phosphorus in swine slurry and cattle feedlot manure. Agron. J. 97:542-548.

Frank, K., D. Beegle, and J. Denning. 1998. Phosphorus. p. 21-26. *In* J.R. Brown (ed.) Recommended chemical soil test procedures for the North Central Region. NC Regional Res. Publ. no. 221 (Rev.). Missouri Agric. Exp. Stn., Columbia, MO.

Kashem, M.D., O.O. Akinremi and G.J. Racz. 2004. Phosphorus fractions in soil amended with organic and inorganic phosphorus sources. Can. J. of Soil Sci. 84:83-90.

Laboski, C.A.M., and J.A. Lamb. 2003. Changes in soil test phosphorus concentration after application of manure or fertilizer. Soil Sci. Soc. Am. J. 67:544-554.

WORKING WITH CUSTOM MANURE APPLICATORS

Kevin Erb [1/]

One out of every three gallons of manure produced in Wisconsin is applied by a custom manure applicator. As of December 2006, there are just under 100 for-hire manure applicators in the state—the smallest handle less than 500,000 gallons each year, the largest over 400 million gallons annually.

A recent informal survey of Wisconsin's applicators showed that less than 3% of farmers are showing the applicator a copy of their nutrient management plan. A slightly greater percentage relies on the custom applicator to suggest a manure rate for a particular field. The vast majority of rate determinations are made by the farmer (who may or may not be relying on their crop consultant for advice).

Keeping in mind the following facts and suggestions will make the nutrient management implementation process easier for the farmer, the crop consultant and the custom applicator.

1. **A single sheet and a map**: Provide each of your clients with a single sheet that lists ONLY the fields to receive manure, acreage, manure rate, and if incorporation is included as part of the nutrient management plan. A map showing the entire farm with those fields highlighted makes the applicator's job easier. The CCA should also put their phone number on the field listing so that if the applicator needs clarification, he can do it quickly and effectively.

2. **The rule of 2's**: Do not plan a different rate for each field. If you can group field by rate (high fields at 15,000 gal/acre, low rate fields at 9,000 gal/acre), mistakes are less likely to happen. Larger farms may have 3 rates.

3. **How low can you go?** Call the farmer's manure applicator in the dead of winter. Find out not only what rates they prefer to use, but also what is the lowest they normally go and how low they actually can apply. It does no good to recommend 4,000 gallons/acre if his equipment can't go below 8,000. Lower rates increase wear and tear and take longer, so they will drive the cost up for the farmer.

4. **Go north in odd-numbered years.** Well, not really. But if you can group fields by location (north this year, west next year), it may reduce costs by eliminating the down time of tearing down and setting up equipment.

5. **Remember the road:** Those low phosphorus fields are prime targets for manure. But if the tanker can't get there easily (low weight limit bridge, field access through neighbor's yard), hold that field until a year when a dragline is available.

6. **A manure sample in the bottle is worth two on the dashboard**. Find out from your client when the applicator is pumping. Make sure a sample is taken, or better yet, do it yourself. A sample taken from the dragline after it's being wound up at the end of the job is worse than no sample at all.

[1/] UW Extension Conservation Professional Development and Training Coordinator.

7. **Madison, Green Bay and Manure Draglines.** Both downtown Madison and downtown Green Bay are laid out on angles. Manure draglines need to be laid out in a similar way. Weird shaped fields will not receive an even application of manure from an inexperienced dragline operator.

8. **Use the off season:** Manure applicators are available during the summer, and making an application before hay or winter wheat can buy your farmer much needed fall flexibility, esp. in wet falls.

9. **Encourage your client to hire a certified applicator.** A trained applicator is more likely to understand the regulations and helps insure that the 590 is implemented more effectively. More than half of Wisconsin's applicators are trained, tested and certified by their professional organization.

10. **Consider a partnership**. Many manure applicators are looking for qualified drivers in the fall season. Creating an employee sharing arrangement with a local manure applicator may help you keep some of your more valued pesticide applicators by providing off-season employment.

More information is available at the PNAAW website at www.wimanuremgt.org

The following is a related paper by Dana Cook

DELIVERY TO FIELD COST, STORAGE, CUSTOM
VS. OWN, CONTRACT HOW'S AND COMPACTION

Dana Cook and Kevin Erb [1/]

Manure Application Cost Considerations: Delivery to field cost, storage, custom vs. own, contract how's and compaction

Making it easier (and less costly) to get manure to the field:

The delivery to field cost varies greatly with distance to the field, road conditions getting to the field (i.e. curvy, stop signs, single lane, poor condition, traveling through town, etc.) equipment used (tractors and tanks, trucks, hose). The best solution to this is to maintain your field roads and driveways. By comparison *it would take you about the same amount of time to travel three miles down a township road as it takes to traverse a 1,500-foot field lane that is rough and full of potholes*. Costs increase for distance traveled also, say you can haul 4 loads per hour three miles away, and only maybe 3 loads per hour at six miles, it will take that many more hours to get the job done.

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Manpower: Having a farm employee at the tractor to load saves the time of the driver having to get out and walk to the tractor, load the tank, and then walk back to the vehicle. Over a day this could save you over an hour or more depending on how many pieces of equipment are hauling with. One other very important factor in keeping cost low is to have a good quality pump with an 8" discharge minimum. The bigger the discharge the faster you can load, which equals more loads hauled in a day. Also a good pump is going to be expensive if you buy your own, so don't skimp on this, if you do skimp, it will cost you more than a good one in the long run, because it will take you longer to pump the pit out over the lifespan of the pump.

Also, if the hauler has not been to you yet or you need to haul after it freezes, DO NOT do any type of tillage in the fields. Spreading on rough ground will take longer, cost more and some haulers refuse to haul on frozen tilled ground. And another problem that arises in fall is that after it is tilled and it gets rained on it takes forever to dry up enough to haul on without dragging mud all over the place, then you have to wait until it freezes, which leads us back to the first problem, frozen tilled soil.

Storage

- Bedding choice: Sand or Mattress; this is a big deciding factor on your pit

    1. Sand-no under barn storage, no pumping into lagoon, gravity flow not recommended, direct push-off into the pit is the best. If you insist on using sand without a direct push off, DO NOT put the parlor water into the reception pit in the barn, or use sprinklers in the barn. This is guaranteed to plug the pipe to the lagoon. Sand is a cheap bedding source, but it is VERY expensive to remove from the pit. One other concern that you need to keep in mind, is what will the sand do to my soil with prolonged use? Hose draggers do not like to pump out sand laden manure. *Many applicators will add a surcharge for sand manure to cover extra wear and tear on equipment.*

    2. Mattresses**—**You can use any style pit that you want to. Some types of wood shavings are too coarse to pump through hoses for the hose draggers. If you are going to have a hose dragger pump your pit, check with them for suggestions.

- Pit placement-under the barn or lagoon, depends on bedding choice, pros, cons, & needs.

    1. Under the barn**—**The main thing to keep in mind if you locate the pit under the barn is how are you going to get the solids out? You are going to NEED an access ramp. They are difficult to agitate because usually cannot see where the solids are filling up at. Plus the piers holding the floor up are a hindrance to agitating. You can use any bedding but sand. You don't get rainwater in the pit, which is a good thing. Because less rainwater equals more capacity for manure. Underbarn pits present a huge safety issue—if one must enter them to remove solids or check agitation, an air supply is a must.

    2. Lagoon**—**The main concern with this is to have enough room available to easily accommodate the equipment that you need to agitate the pit. Which relates to about 150 feet around the outer edge of the pit wall or lagoon bank. Round pits agitate the easiest. If this is impractical a long and narrow pit is easier to work with than a large square lagoon. Try not to get over 150 feet wide, at the top of the lagoon. Any bedding is acceptable. Stirring pads are required as a minimum to keep from ruining the liner. It is highly recommended though to have a concrete ramp and the bottom in the pit. It is a MUST if you use sand! Make sure the ramp will be easy to negotiate when pulling a loaded spreader out of the pit.

3. General needs for all pits—An easy access road to the pit area. It should be wide enough to allow the equipment to easily pass if you only have one way in and out. Keep in mind that the equipment is between 9 to 16 feet wide with injectors on the tank. And large trucks can be upwards of sixty feet long. A large area to accommodate more than one piece of equipment in the loading area to get situated to back under the load pipe. It is nice to have a level loading area that is a good gravel base at a minimum. If you have the means, a loading area that is concrete with a drain running back into the pit is nice to keep the mess contained better. Also a flow through system (enter one driveway and exit another) for the equipment works the best. Especially if you can keep it away from the buildings and other daily activities on the farm. How is the pit location going to fall into the further expansions in the future? Will the needed accommodations for hauling manure out, still be met? Also if you plan on having a custom hauler do your hauling, contact them prior to building an see what type of equipment that they have and what kind of needs that will be required to get their equipment into the pit properly. Simple things such as this are time and money savers in the long run. Even if you want to haul your own manure and you are not sure of some of the planning or concerns for your pit, or even questions concerning equipment, contact a custom hauler or two and get some ideas and opinions. Because it is easier to change it before it is built or bought.

Custom vs. own

- Custom hauler or self hauling- pros & cons:

  1. Custom hauler—Pros-most or all of the equipment is supplied by the hauler. No costs to the producer for equipment purchases and maintenance costs. The custom hauler can bring in several units to get the job done faster than the producer could haul on his own. We can get the job done in days compared to weeks. If the hauler certified by the Professional Nutrient Applicators Association of Wisconsin, they will know what the rules and the latest changes are. And they should spread accordingly, if supplied with the correct up to date nutrient management plan for the farm. This gives the producer more time to focus their abilities to other projects, without having to be constantly checking up on the hauling progress.

  2. Custom hauler—Cons-not always available to haul the exact time that the producer is ready to go. Rain affects scheduling of jobs, for every day it rains; you can add 2 days in delays. Crops can also hold the season up and put the custom hauler way behind. You need to be patient, especially in the spring.

- Self hauling-Pros—set-up and go whenever you want to.

  1. Self hauling-Cons—The equipment is very expensive to have sitting around for 11 months of the year. Time is money; you will be spending weeks doing what a custom hauler can do in days. Equipment costs- truck set up properly with floatation tires, \$50,000-\$80,000; tanker \$10,000-\$60,000, with injectors add up

to another $10,000, plus the cost of properly sized tractor to pull it; hose system- $80,000-$250,000 depending on the type, size and amount, reel size, and tool bar. Plus a properly sized tractor to pull it. A good pump $14,000-$26,000.

2. Other things to keep in mind—
Neighborhood spreading- i.e. the custom hauler spreads several farms next to one another rather than go to one county today, and a farm in another county tomorrow. It can take several hours to take down equipment and travel on lengthy moves compared to hauling your way through a neighborhood. But one thing that you absolutely must have is good planning amongst neighbors to be ready when the haulers come through. This includes having your tractors fueled, radiators blown out, and ready when they get there. The pit agitated ahead of time if you have your own pump, and a good plan of where the manure will be hauled and how much to apply. These simply things will save you time and money. Off season spreading (June, July, August) schedule your crop rotation to be able to haul during the summer month, by planting canning crops or wheat.

Contracts

- Contracting can be extremely difficult to say the least. A lot of the haulers will not even get involved with contracts. It creates too many problems with logistics when hauling season is in full swing. This is like planning a harvesting date before the crops are even planted. There are too many variables. We all realized that farming is not a scheduled event. The best approach to take is to get to know the custom haulers operation or operating habits and to have a good working relationship with them. Most haulers are well aware of the need to haul in a timely manner, and get stressed out as easily as a producer who is waiting for their arrival, when the weather and crops turn against them. Ask other producers about them if you are interested in their services. Always be cautious when someone you are not familiar with is trying to talk you into contracting with them. Ask for references that you can contact or call other haulers and ask about the person or company in question. There are cases of individuals being talked into something that they normally would not do and it has cost them. An example would be prepaying for hauling, then they haul one day and they give you an excuse that they need pull out, not to be seen again. It has happened.

  Also not contracting allows you to keep your options open. You have the right to select anyone that you feel comfortable with. There are several producers who will call several haulers, and the hauler who shows up first gets the job. If you take this approach make sure you call everyone back that you have called and tell them that their services will not be needed. Also keep in mind that using this approach, it is like the little boy that cried wolf, pretty soon you will not be priority to any one. This is not good practice to get into.

Compaction

- Great strides have been made in manure hauling equipment to address compaction issues. Tires are larger and wider to spread weight out over a larger area. Tire companies are addressing the issues of truck tire compaction and are coming up with some really good floatation tires that are small enough to fit on the trucks and carry the heavy loads and give superb floatation with substantially less compaction. Less compaction equals higher yield, which benefits your financially.

Nutrient management and maps

- You need to have a plan before you start pumping. This is where a lot of producers struggle. You have a lot of fertilizer potential going to waste or used in an uneconomical fashion. They fail to recognize the money that they could be saving in fertilizer costs, by simply applying manure correctly for future crop needs. This is where a good crop consultants or agronomist is worth his or her weight in gold. They can tell you how much manure to apply to meet crop demands. And have it specified by field and available for the hauler to have in their possession when hauling.

  It is critical to have field maps that are easily legible and accurately labeled, with the field id number, the application rate, set backs and non-spreading areas or any other specifics for the field being spread. Have enough maps available for all the haulers.

  Some farms are beginning to post field names at the ENTRANCE to the each field so sprayers, manure haulers, etc know exactly where they are. If this is not feasible for your operation you should, at a minimum , take the crew leader to the field or fields and explain exactly what you want applied and where. This will hopefully insure that there is no confusion.

NOTES

1. **Can you break even on manure—**Liquid dairy manure per thousand gallons, total nutrient value is 28-9-20, but first year available to nutrients are 10-5-16 (assuming that incorporation is within 72 hours of application). 7-5-16 if after 72 hours. Value is $16 per thousand gallons total, but we use first year availability, which is $8-$9 per thousand gallons. Hence if a tanker holds 4,000gallons, the value is $28-$32 per tanker load. Use $25 per tanker to make math easy. With 4 tankers hauling and you get 16 loads per hour hauled at a value of $400 per hour. Cook's charge $65 per hour, per tanker, for a cost of $260 per hour, for 4 tankers (farmer provides fuel). Manure value is almost double the hauling cost. The crop does not use all available nutrients, this year. For every 4,000 gallons of manure applied to the acre during corn years (assuming 125# of 9-23-30 starter), saves you money later in the crop rotation. That 4,000 gallons equals the potassium in 100# of 0-0-60 top dressed on alfalfa. Over the long term it all evens out. If we look at corn recommendations at the optimum soil test level, it calls for 160# N, 55# phosphates, and 35# potash.

   At current fertilizer values, crop removes $58 in N plus $27 in phosphate and potash, or $85/acre in fertilizer to produce 160 bushel corn.

2. **The most important point—**Manure slowly releases its nutrients throughout the growing season, compared to commercial fertilizers that are quick releasing. Which means if your commercial fertilizers are not applied at the proper time, they may have already gone through the soils, and are not being of any benefit to the crops. Where as, manure is continually breaking down and feeding the crops throughout the growing season.

3. **Parlor water—**Dilution factors vary from parlor water. Most producers have a high amount of water usage in washing down the parlor until they get a system worked out that is efficient, especially when it is new to them. Also keep in mind that different employees have different priorities that may contribute to excess water usage, which may require some extra training to work out. The most economical parlors recycle their water when they can, for flushing.

4. **Rain water—**A lot of producers fail to recognize the important of rain gutters and water diversion dikes. Here is an example why they are a money saver.

   For every square foot or roof or ground area, that drains water into the lagoon, you lose capacity for manure. (1 inch of rain per square foot gives you .62 gallons in the pit, or 17.5 gallons yearly per square foot, based on a normal yearly rainfall.) Therefore a free stall barn at 300 by 60 means that 315,289 gallons of rainwater will enter the lagoon, (roof areas is square foot of ground covered, not the square foot of the roof surface area). Based on a 4000 gallon tanker hauling 4 loads an hour, it will take approximately 19.7 hours to haul the water. At a cost of $65 per hour this will cost $1280.50, every year. What do you think about wasting money on gutters now? 315,289 gallons of water would be equal to using 430 gallons per milking (2x) for parlor wash down.

5. **Injection on conservation plans—**Number one, most plans are flexible. Most counties will work with the producer to modify it as manure application and crop rotation changes. Use manure injection as primary fall tillage.

   No-till—Options are more limited. Zone tillage or strip tillage works. Aer-way is also an option. Another option is to fall seed rye, wheat or barley before injection, or apply early and seed after incorporation.

6. **Pit sizing and designs—**I recommend using at a minimum 35 gallons per cow per day. That may sound like a lot to some of you, but this also takes into account the water used to wash down the parlor. See Parlor water above. Also by code you are supposed to have 2 feet of freeboard in your pit at all times. This is one point that I see violated all the time. Another thing that is always missed is that unless you have a sump in your pit and it is sloped properly to the sump, your over all pit capacity is reduced because depending on what type of pump you have, there will always be anywhere from 6 to 18 inches of manure left in your pit which will greatly reduce your overall capacity. Make sure that you add all these points to your planning for overall pit capacity. One last suggestion, although there are some good engineers out their designing pits, they are more accustom to concrete and rebar than they are to manure and manure handling equipment needs and use. So with that said I highly recommend having a custom hauler look over your plans and location to give you some good information on what will and will not work. It is easier to change the pit before it is installed, than trying to change it afterwards.

This outline was put together for you on behalf of the Professional Nutrient Applicators Association of Wisconsin. If you have any questions, comments, concerns, or would even like to become a member of the Association, please direct them to:

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RESIDUE MANAGEMENT – HORIZONTAL VS. VERTICAL TILLAGE

Ronald T. Schuler [1/]

Introduction

Agricultural machinery manufacturers are providing more equipment options for crop growers to manage crop residue and provide the soil conditions to increase the potential for maximum productivity. With higher crop yields and improved crop varieties with respect lodging and pest resistance, managing crop residue becomes more challenging. Much of the tillage equipment can be grouped into vertical or horizontal tillage. Many manufacturers are marketing vertical tillage equipment with a wide range of characteristics. Based on the performance characteristics of the equipment on the market, vertical tillage has several definitions.

Setting Tillage Goals

When a crop grower is considering the purchase and operation of tillage equipment, tillage and residue management goals should be identified. Some questions to answer when identifying these goals are:

1. What quantity and distribution of surface residue do you want to have after the operation?
2. What quantity of residue is present before the operation?
3. What is the condition of the crop residue-partially standing corn stalks or flattened-chopped residue?
4. What are the soil characteristics–shallow or deep soil, compacted areas and depth?
5. What volume of soil do you want to loosen–horizontal in a uniform layer or vertical in non-uniform layer across the width of a machine?
6. What tillage depth should you consider?
7. What soil surface roughness or smoothness is desired?
8. What is the root pattern of the preceding crop–signs of soil compaction due to tillage or wheel traffic?

Once the tillage goals are identified from the answers to these questions, tillage equipment can be identified and adjusted to meet these goals. Following are some general guidelines to consider:

1. If compacted conditions exist, the tillage depth should be 2 inches below the compacted layer. Dealing with compaction will usually require vertical tillage.
2. If a smooth soil surface is desired, horizontal tillage can be used or vertical tillage with very little soil inversion or a leveling attachment may be useful.
3. If large quantities of crop residue need to be buried, some soil inversion will be needed.
4. If crop residue needs to be sized smaller, some cutting coulters or disks may be needed.
5. If strips of soil must be cleared of crop residue for better soil warm-up, some form of strip or zone tillage may be needed.

These are just a few scenarios that can be considered to meet the tillage goals. Becoming familiar with the equipment on the market and its operating characteristics will minimize potential errors and problems resulting from incorrect soil conditions.

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Horizontal Tillage

Horizontal tillage has been described as a broadcast tillage which creates horizontal layers of soil having layers of different soil densities. Historically, the moldboard plow has been known to produce the dense, compacted plow layer which influenced root patterns. Chisel plows with sweeps with a width greater than the shank spacing will create a horizontal layer. Other tillage machines creating horizontal layers include field cultivators and soil finishers.

Although some of these tillage machines do not create a very dense layer, the change in soil density influences the root pattern. As the root initially develops in and adjusts to the upper-less dense layer, the roots may grow in a horizontal pattern when it reaches the slightly denser layer.

With horizontal tillage, mechanical weed control is more effective reducing the need for chemical weed control. More crop residue is buried with horizontal tillage which may be a problem in soil conditions susceptible to soil erosion due to wind or water. The soil at the soil surface is more uniform with regard to surface roughness and density, which results in better planter performance and more uniform emergence.

The density changes in layers leads to changes in the rate of water movement into the soil profile. When a rainfall event occurs, the water can move more rapidly through the less dense surface layer than through the denser layer below. Some conditions may lead to greater risk of sufficiently high water content in the soil just above the dense layer for short periods of time to impact root development.

Vertical Tillage

Vertical tillage frequently involves deeper tillage and tool spacing such that soil disturbance depth between the tillage shanks or tools is less. The most common implements in this group are subsoilers, rippers, and chisel plows with straight or twisted shovels. Many combination tillage machines having disks or coulters in front of deep tillage shanks followed by tillage tools to modify residue cover and influence surface roughness condition are readily available on the US farm equipment market.

Several machines referred to a vertical till machines have very different characteristics. Two short line manufacturers have a vertical till attachment for chisel plows. On the chisel plow shank, the shovel is replaced with two fluted coulters, to till about an 8-inch wide strip of soil to a depth of 3 to 4 inches. The coulters have a diameter of about 17 inches and are spaced 6 inches apart. These coulters obviously will not address compaction problems beyond 4 inches but do provide a strip of loosened soil with less surface residue which may enhance planter performance over no-till. Two these manufacturers are Wil-Rich and Yetter.

Another family of tillage implements described as vertical tillage machines has a rolling soil engaging tools. These shallow tillage machines create little or tillage beyond 3 inches and can be used to reduce the roughness of the soil surface. Examples of this equipment are Aerway and Phoenix rolling tillage machines.

Numerous studies have been conducted evaluating the performance these vertical tillage machines primarily dealing subsoiling. Very few studies have identified vertical tillage as a specific treatment. One study was conducted in Iowa.

In a vertical tillage study, Van Dee (2004) reported research comparing conventional, no-till and vertical till system in corn. The conventional system consisted of spring disking and field cultivation. The no-till consisted of planting directly into soybean stubble. For the vertical till, he used a spiked rolling harrow making a single pass. Although this was a 1-year report, small differences in corn yield were observed.

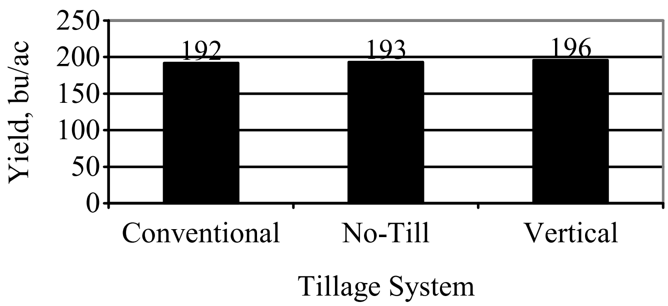

Figure 1. Iowa tillage study in one year of corn.

The traditional vertical tillage machines are designed primarily to address soil compaction issues beyond six inches. They create a soil environment to allow good root development beyond the six inch depth. Since most vertical tillage machines do not till the complete soil surface, most vertical systems will require herbicide weed control. With more surface residue and the potential for a rougher soil surface, proper planting will require more attention to ensure high and uniform emergence rates. If surface roughness is excessive, a soil leveling attachment is needed or a separate leveling operation may be needed.

Summary

Setting goals for the tillage system and learning about the performance of the tillage implement on the market will increase the potential of a successful tillage. Getting to know the soil conditions with respect to compaction and depth and studying the rooting patterns of previous will prove to be very useful. The plant's roots can provide a great deal of information to identify problems if they exist. Vertical tillage can provide a solution to these problems, but there is a large variety of this tillage equipment on the US market.

References

Smith, D. 2006. Tillage road map. AgWeb.com. Accessed 12/23/2006.

Van Dee, K. 2004. Vertical tillage study. Iowa State Univ., Southeast Research and Demonstration Farm, ISRF04-34.

ADJUSTING TILLAGE PRACTICES IN A CORN/SOYBEAN ROTATION

Richard P. Wolkowski [1/]

Abstract

Grain crop producers often rotate tillage management to meet soil conservation goals or disrupt yield-limiting soil conditions. A long-term tillage study containing plowed and no-till treatments was modified in 2005 to evaluate the effect of tillage change on soil properties and crop yield on a Plano silt loam soil at the Arlington Agricultural Research Station. Tillage treatments included continuous chisel tillage, the same chisel tillage converted to no-till, continuous no-till, chisel tillage of the same no-till, and strip-tillage. Tillage of the no-till resulted in soil test, penetrometer resistance, and bulk density levels similar to that of continuous chisel and improved early season K uptake by corn. Converting the chisel plowed treatment to no-till increased penetration resistance, bulk density, and decreased K uptake. Yield tended to be highest where the no-till treatment was tilled and lowest where the chiseled treatment was rotated to no-till. These preliminary results showed that tilling continuous no-till may improve soil quality parameters as evidenced by the lower bulk density and penetration resistance, which enhanced nutrient utilization and crop growth and yield. Conversion of plowed ground to no-till reduced these soil quality factors, as well as crop yield and growth possibly due to changes in soil consolidation.

Introduction

Recent erosive rains have amplified the need for reconsideration of the tillage systems used on many Wisconsin soils. Erosion has been evident in many fields, even where considerable residue was left on the surface by chisel plowing and other mulch-tillage systems. Tillage has a profound effect on the soil condition due to changes in residue coverage and soil consolidation. Mulch tillage systems have less runoff initially when compared to no-till because of storage in depressions. However, once secondary tillage is conducted and the crop is planted the soil is more susceptible to erosion. Switching to a no-till cropping system is an accepted way to reduce soil erosion, but it is not without its problems.

Many producers are reluctant to adopt long-term no-till because of a yield penalty that has been associated with this system, especially in northern portion of the Corn Belt. No-till systems, which leave large amounts of residue, protect the soil, but also cause cooler and wetter soil conditions that slow emergence and early growth (Moncrief, 1981; Wolkowski, 2000). Other concerns with no-till systems include higher surface bulk density that reduces porosity (Hill et al., 1985), increased penetration resistance that interferes with root growth (Kaspar et al., 1991), and increased N loss via denitrification (Hilton et al., 1994) and N immobilization (Karlen et al., 1994). Recent research has shown that no-till and strip-till systems are more responsive to P and K fertilization, especially within a corn/soybean rotation (Wolkowski, 2003). For these reasons, the adoption of no-till in Wisconsin lags significantly behind states further south.

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Benefits beyond those related to soil conservation have been observed in no-till systems. Producers that have successfully applied no-till management have touted these for years. These benefits include improvements in aggregate stability (Kladivko et al., 1986), moisture retention during dry periods (Hill, 1990), and C storage (Karlen et al., 1994). Anecdotal suggestions are often made that no-till systems require several years to equilibrate and produce yields equal to those where tillage is performed. There is limited research available to support this claim.

Crop producers are very interested in the influence of tillage on crop growth and the soil condition. The idea of rotational or occasional tillage to loosen the soil has been explored by Pierce et al. (1994), who found that plowing a long-term no-till soil produced soil physical conditions similar to continuously plowed soils. If plowing is ceased the soil returns to the conditions found in continuous no-till in a few years. They indicated that one of the significant benefits of periodic plowing is the redistribution of immobile nutrients, such as P and K, and amelioration of the acidic surface pH which results from the surface application of ammonium-containing fertilizers.

This study is being conducted to evaluate two broad scenarios of tillage management in grain crop rotations. These are the potential benefit of the one-time tillage of a long-term no-till treatment on a site that has shown yield depression in no-till compared to chisel tillage, and the consequence of converting tilled fields to no-till. The latter would determine if in fact there is a period required for no-till yields to equilibrate with those of other systems.

Materials and Methods

A tillage/rotation study that was established in 1997 near Arlington, Wis., USA on a Plano silt loam (Typic Argiudolls) was used for this study. This study utilized three existing rotations [continuous corn (CC), corn following soybean (SbC), and soybean following corn (CSb)], established five tillage treatments (long-term fall chisel/spring field cultivator, fall strip-till, and no-till; long-term chisel that converted to no-till in 2005 and long-term no-till that was converted to chisel plow in 2005; and one-time/one-year tillage conversion with return to the original tillage system), and three P and K fertilizer placement methods (none, fall pre-tillage broadcast, planter-applied 2 x 2 inches – below and to the side of the seed). Row cleaners were not used in the no-till system. Fertilizer was applied at rate of 200 lb 0-23-30/acre. Supplemental N was applied to the corn following University of Wisconsin recommendations. Treatments were replicated four times in a split-split plot treatment arrangement where rotation is the main plot, tillage is the subplot, and fertilization is the sub-subplot. The individual plot size was 10 x 35 feet (four 30-inch rows). All treatments were replicated four times. A full season corn hybrid (DeKalb DKC53-34RR and Renk RK636-RRYGCB) and soybean variety (Kaltenberg KB221RR and Asgrow AG2107RR) were planted in early May 2005 and 2006, respectively using a four row Kinze planter (Kinze Mfg., Williamsburg, IA, USA).

Measurements made included: (1) population; (2) surface crop residue; (3) early growth and nutrient uptake at the V6 growth stage; (4) incremental soil samples, (5) soil bulk density, (6) cone penetrometer resistance, and (7) yield. Population counts were made by counting the number of plants visible along a measured length of row after the majority of plants were emerged. Three crop residue measurements were taken using the line-transect method in each tillage plots. Early season corn plant samples were taken at the V6 growth stage in corn by collecting ten plants per plot. These were dried, weighed, and ground for analysis. Incremental soil samples were collected in mid-June by taking nine cores to 8 inches from each plot, which were then subdivided into 2-inch increments. All samples were analyzed for routine soil test parameters using University of Wisconsin laboratory procedures. Bulk density was measured by collecting intact cores to 9 inches and subdividing these into increments of 3 inches. Penetrometer measurements were made with a constant-rate penetrometer interfaced with a load cell and data logger. Yield was measured by harvesting the middle two rows of the four-row plots with a small plot combine. Wheel traffic was avoided in the middle two rows.

Data were analyzed with an analysis of variance for a split-split plot treatment arrangement using SAS (Statistical Analysis System, Cary, NC). Where significance is found at the $p<0.05$ level a Fisher's LSD was calculated.

Results and Discussion

The 2005 and 2006 crop years were unique with respect to weather conditions. Periods of moderate drought, accompanied by warm temperatures, were experienced in early summer. Adequate mid-season rain arrived at pollination and crop yields in the region were much better than generally anticipated.

Table 1 shows the main effect of tillage treatment on the incremental soil test values collected in 2005. These results show the surface acidification associated with the rotation components which were planted to corn in 2005 (CC and SbC). The pH in the 0- to 2-inch increment was depressed by about a full pH compared to that measured in the CSb treatment. This effect was also observed in the 2- to 4-inch increment. Soil test P was generally not affected by rotation and was in the excessively high category throughout the top 6 inches. Soil test K in the 0- to 2-inch layer was higher in the continuous corn treatment, compared to the treatments that contained soybean. Corn stover will cycle much more K compared to soybean and at normal yields corn grain removes less K compared to soybean. The combination of these effects likely accounted for the higher soil test K in the surface of the continuous corn system. Tillage affected soil test as expected. Soil pH and soil test P and K were higher in the no-till and strip-till treatments in the surface increments. Tillage of the long-term no-till removed the stratification to the extent that soil test levels were similar to those found under chiseling. Fertilization as expected resulted in higher soil test P and K levels in the top 10 cm of soil.

The effect of the rotation and tillage treatments on the soil bulk density measured in 2005 and 2006 is shown in Table 2. Overall bulk density values were typical for a silt loam soil. Those measured in 2005 in the top 6 inches of the no-till and the un-tilled chisel treatment may be considered as high enough to limit porosity or inhibit root growth, although the values moderated somewhat in 2006. Measurements were taken in late June, just prior to canopy closure. Therefore full consolidation of the soil had likely not occurred. Cores were taken from the non-wheel trafficked areas of the plots so that results represent the effect of rotation and tillage. Care was taken to avoid incidental traffic from tillage or spraying activity. The only "traffic" this area would have received was that of the planting unit the previous season as rows were alternated 15 inches each year. Rotation did not appear to have an effect on bulk density. Tillage affected bulk density substantially. Where chisel tillage was converted to no-till the bulk density increased and was found to be close to that in continuous no-till. Similarly, tilling the long-term no-till resulted in bulk density levels equivalent to that found in the long-term chisel system. These effects were most notable in the top 15 cm of soil suggesting that the chisel plow did not substantially disrupt the soil below this depth.

Table 1. Main effect of tillage on the incremental soil test, Arlington, Wis., 2005.

	0 to 2 inches			2 to 4 inches			4 to 6 inches			6 to 8 inches		
Treatment	pH	P	K	pH	P	K	pH	P	K	pH	P	K
		--- ppm ---			--- ppm ---			--- ppm ---			--- ppm ---	
Tillage †												
Chisel	6.0	49	141	6.4	44	104	6.8	35	77	6.9	27	68
CH → NT	5.9	51	142	6.4	42	89	6.8	36	22	6.9	27	68
No-till	5.7	59	150	6.7	42	93	6.9	38	74	6.8	29	68
NT → CH	5.9	46	136	6.3	39	104	6.8	34	80	6.9	28	71
Strip-till	5.9	68	176	6.7	45	99	7.0	40	75	7.0	32	71
Pr>F	0.38	<0.01	<0.01	<0.01	0.74	0.08	0.03	0.81	0.21	0.14	0.70	0.03
LSD	NS ‡	12	19	0.2	NS	NS	0.1	NS	NS	NS	NS	5

† Tillage: Chisel = Fall coulter chisel with twisted shovels, spring field cultivator 1x since 1997; CH → NT = Chisel system since 1997 and left un-tilled in 2005; No-till = No-till since 1997; NT → CH = No-till since 1997 and chiseled in the fall of 2004; Strip-till tool consists of residue clearing coulters, knife to 15 cm, and notched closing coulters. Rows alternated 15 inches each year.

[b] NS, not significant.

Table 2. Effect of rotation and tillage on the soil bulk density, Arlington, Wis., 2005 and 2006.

		Tillage system †							
Rotation	Depth	Chisel		CH → NT		No-till		NT → CH	
	inch	g cc $^{-1}$							
		2005	2006	2005	2006	2005	2006	2005	2006
CC	0 - 3	1.17	0.96	1.42	1.22	1.38	1.24	1.13	1.00
	3 - 6	1.24	1.05	1.43	1.25	1.46	1.42	1.29	1.21
	6 - 9	1.35	1.23	1.39	1.17	1.48	1.41	1.45	1.32
CSb	0 - 3	1.21	1.05	1.26	1.24	1.42	1.16	1.20	0.98
	3 - 6	1.23	1.15	1.27	1.30	1.44	1.36	1.23	1.12
	6 - 9	1.43	1.22	1.40	1.37	1.44	1.35	1.42	1.29
SbC	0 - 3	1.24	1.06	1.34	1.14	1.36	1.12	1.14	0.98
	3 - 6	1.32	1.35	1.36	1.30	1.46	1.36	1.23	1.00
	6 - 9	1.40	1.33	1.42	1.34	1.45	1.41	1.44	1.18
Significance (Pr>F)		0 - 3		3 - 6		6 - 9			
		2005	2006	2005	2006	2005	2006		
Rotation		0.95	0.28	0.03	0.75	0.95	0.57		
Tillage		<0.01	<0.01	<0.01	<0.01	0.08	0.01		
T*R		<0.01	0.65	0.10	<0.01	0.55	0.05		

†Tillage: Chisel = Fall coulter chisel with twisted shovels, spring field cultivator 1x since 1997; CH → NT = Chisel system since 1997 and left un-tilled in 2005; No-till = No-till since 1997; NT → CH = No-till since 1997 and chiseled in the fall of 2004.

The bulk density measurements were confirmed in the results of the cone penetrometer. These data are presented in Fig. 1 and shows that the long-term chisel and recently tilled no-till had similar penetration resistance. The highest resistance was found in the long-term no-till. Resistance values in chisel converted to no-till were intermediate to those found in chisel and no-till.

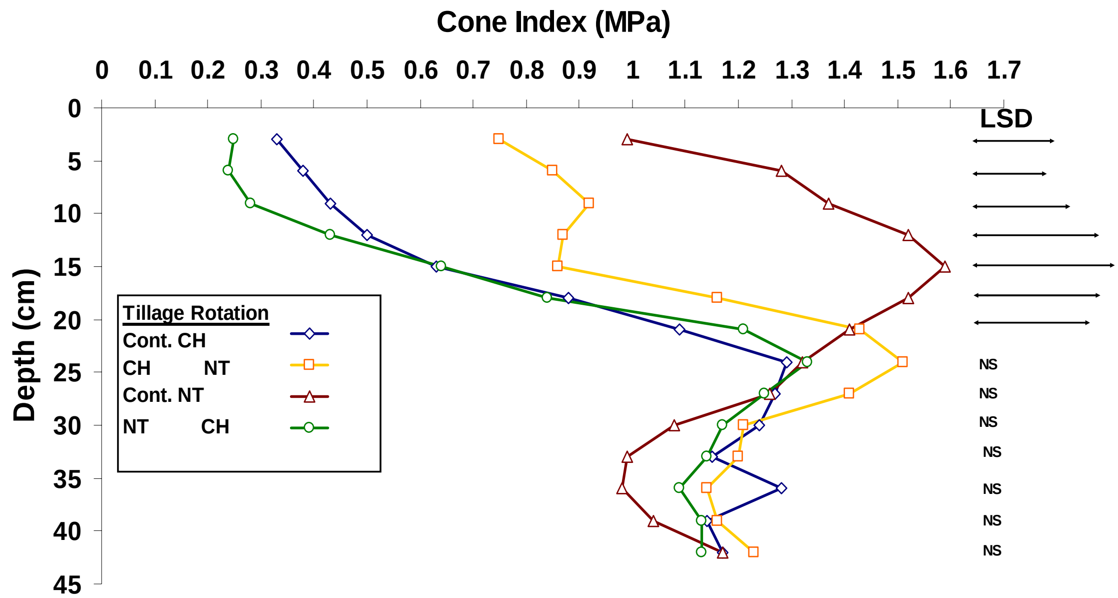

Fig. 1. Cone penetration resistance measured in the tillage rotation study, Arlington, Wis., 2005.

The effect of rotation, tillage, and fertilization on the early season uptake of K by corn in 2005 is shown in Table 3. Uptake is the product of nutrient concentration and dry matter production. Previous studies have demonstrated reduced K uptake in no-till, often inducing visible K deficiency symptoms. Rotation did not affect K uptake. Potassium uptake was lowest in the treatment where long-term chisel was converted to no-till and highest in the long-term no-till converted to chisel. This confirms the effect of the reduction in K uptake in no-till systems is immediate and is probably related to soil properties that control K absorption by the plant. Fertilization with the planter in a 5 x 5 cm placement resulted in higher K uptake compared to broadcast confirming the efficiency of this placement method.

Table 4 shows the corn grain yield for 2005 and 2006. Surprisingly there was no yield difference between continuous corn and first-year corn after soybean. The effect of tillage was not significant in 2005; however, there was a trend for response (Pr>F = 0.11). The highest yielding treatment was found in the no-till that had been chiseled. The lowest yield was in the long-term chisel converted to no-till. The tillage effect was highly significant in 2006. The highest yield was found in both the long-term chisel and no-till converted to chisel plowed. The lowest yield continued to be the converting long-term chisel plowing to no-till. While these responses cannot be explained at this time it is possible that improved aggregate stability in no-till persisted after tillage and provided an optimal root bed. The early season response to the 2 x 2 placement of fertilizer in 2005 was expressed in yield as this treatment produced a corn yield greater than that where broadcast was used. The response to fertilization was also highly significant in 2006; however there was no difference between broadcast and row placement.

Table 3. Effect of rotation, tillage and fertilization on the K uptake by corn at the V6 growth stage, Arlington, Wis., 2005.

		Tillage system ‡				
Rotation	Fert. †	Chisel	CH → NT	No-till	NT → CH	Strip-till
		------------------------- lb K a^{-1} -------------------------				
CC	None	8.9	5.5	8.6	12.4	8.2
	Bdct.	16.6	10.0	10.9	18.6	14.7
	Row	20.3	14.1	16.3	22.1	21.2
SbC	None	8.3	5.5	5.5	6.7	4.7
	Bdct.	11.0	7.1	11.1	16.1	13.0
	Row	20.3	19.3	19.9	25.4	13.4
Significance (Pr>F)						
Rotation	0.31					
Tillage	<0.01					
T*R	0.59					
Fert.	<0.01					
R*F	0.07					
T*F	0.56					
R*T*F	0.13					

† Fertilizer: Broadcast=200 lb 9-23-30/acre in fall 2004 or row=2 x 2 planter placement.
‡ Tillage: Chisel=Fall coulter chisel with twisted shovels, spring field cultivator 1x since 1997; CH → NT=Chisel system since 1997 and left un-tilled in 2005; No-till=No-till since 1997; NT → CH=No-till since 1997 and chiseled in the fall of 2004; Strip-till tool consists of residue clearing coulters, knife to 15 cm, and notched closing coulters.

Table 4. Effect of rotation, tillage and fertilization on the corn grain yield, Arlington, Wis., 2005 and 2006.

		Tillage system ‡									
Rotation	Fert. †	Chisel		CH → NT		No-till		NT → CH		Strip-till	
		--------------------------- bu a^{-1} ---------------------------									
		2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
CC	None	172	194	164	131	167	159	198	217	182	177
	Bdct.	182	217	179	168	174	161	194	220	186	178
	Row	191	220	183	169	186	178	186	223	191	188
SbC	None	182	183	171	182	175	166	177	167	175	190
	Bdct.	183	216	169	186	188	204	198	210	202	217
	Row	190	217	204	201	202	209	206	209	196	208
Significance (Pr>F)											
	2005	2006									
Rotation	0.32	0.32									
Tillage	0.11	<0.01									
T*R	0.86	0.03									
Fert.	<0.01	<0.01									
R*F	0.05	0.24									
T*F	0.15	0.96									
R*T*F	0.01	0.32									

[a] Fertilizer: Broadcast = 200 lb 9-23-30/a in fall 2004 or row = 2 x 2 planter placement.
[b] Tillage: Chisel = Fall coulter chisel with twisted shovels, spring field cultivator 1x since 1997;

CH → NT = Chisel system since 1997 and left un-tilled in 2005; No-till = No-till since 1997; NT → CH = No-till since 1997 and chiseled in the fall of 2004; Strip-till tool consists of residue clearing coulters, knife to 15 cm, and notched closing coulters.

Conclusions

This paper focuses on the results of a study that examined the effects of tillage rotation on soil properties, crop growth, and yield. Tillage of a continuous no-till system (8 years) reduced bulk density and penetration resistance to that where tillage was continuous, removed much of the soil test stratification in the surface layers, enhanced early-season K uptake, and tended to increase yield. The omission of tillage for one season resulted in higher soil bulk density and penetration resistance approaching those measured in continuous no-till, reduced early season K uptake, and tended to decrease yield. The responses are likely in part due to changes in the soil root zone condition, such as improved aeration and water relationships. This may explain some of the problems growers experience when converting to no-till from aggressive tillage systems. Strip tillage was a reasonable alternative to chisel tillage. Research will be continued to explain these responses.

References

Hill, L.R., R. Horton, and R.M. Cruse. 1985. Tillage effects on soil water retention and pore size distribution of two mollisols. Soil Sci. Soc. Am. J. 49:1264-1270.

Hill, L.R. 1990. Long-term conventional and no-tillage effects on selected soil physical properties. Soil Sci. Soc. Am. J. 54:161-166

Hilton, B.R., P.E. Fixen, and W.J. Woodard. 1994. Effects of tillage, nitrogen placement, and wheel compaction on denitrification rates in the corn cycle of a corn-oats rotation. J. Plant Nutr. 17:1341-1357.

Karlen, D.L., N.C. Wollenhaupt, D.C. Erbach, E.C. Berry, J.B. Swan, N.S. Eash, and J.L. Jordahl. 1994. Long-term tillage effects on soil properties. Soil Tillage Res. 32:313-327.

Kaspar, T.C., H.J. Brown, and E.M. Kassmeyer. 1991. Corn root distribution as affected by tillage, wheel traffic, and fertilizer placement. Soil Sci. Soc. Am. J. 55:1390-1394.

Kladivko, E.J., D.R. Griffith, and J.R. Mannering. 1986. Conservation tillage effects on soil properties and yield of corn and soya beans in Indiana. Soil Tillage Res. 8:277-287.

Moncrief, J.F. 1981. The effect of tillage on soil physical properties and the availability of N, P, and K to corn (*Zea mays* L.). Ph.D. thesis. Univ. of Wisconsin–Madison.

Pierce, F.J., M.C. Fortin, and M.J. Staton. 1994. Periodic plowing effects on soil properties in a no-till farming system. Soil Sci. Soc. Am. J. 58:1782-1787.

Wolkowski, R.P. 2000. Row-placed fertilizer for maize grown with an in-row crop residue management system in southern Wisconsin. Soil Tillage Res. 54, 55-62.

Wolkowski, R.P. 2003. Wisconsin corn and soybean responses to fertilizer placement in conservation tillage systems. Proc. Wis. Fert., Aglime, and Pest Mgmt. Conf. 42:99-106.

IS THE CORN-SOYBEAN ROTATION IN TROUBLE? EVIDENCE FROM THE LANCASTER ROTATION EXPERIMENT

Joe Lauer and Trent Stanger [1]

Sustainable agriculture is a practice that over the long term enhances environmental quality and the resource base on which agriculture depends, provides for basic human food and fiber needs, is economically viable, and improves the quality of life for farmers and society (White et al., 1994). Generally, increased diversity of crops grown in rotation enhances sustainability of agriculture systems because crops grown in rotation, with similar off-farm inputs, have greater yield than those grown in monoculture (Mannering and Griffith, 1981; Dick et al., 1986; Higgs et al., 1990).

Many reports show yield benefit for rotated corn over continuous corn. Raimbault and Vyn (1991) reported that first-year corn grown in rotation yielded 4% more than continuous corn under fall moldboard plow and 8% more than continuous corn under fall chisel. Peterson and Varvel (1989b) found that corn grown in a 4-yr rotation and fertilized with 160 lb N A^{-1} yielded 22% more than continuous corn fertilized at the same rate. Katsvairo and Cox (2000a, b) showed that under high chemical inputs and chisel plow, a 3-yr rotation (that included a legume) yielded 16% more than continuous corn, while under moldboard plow, the 3-yr rotation yielded 22% more than continuous corn.

The merits of extended crop rotations that include forage or pasture crops have been debated for centuries (Karlen et al., 1994). The key benefits of including a forage or pasture crop consist of increase carbon retention in the surface horizon and a more even distribution of labor needs and risk due to climate or market conditions than those involving only grain or fiber crops (Magdoff and van Es, 2000). Crop rotations that include legumes also increase soil N levels (Peterson and Varvel, 1989a; Raimbault and Vyn, 1991). Karlen et al. (2006) and Wienhold et al. (2006) have also suggested that extended rotations have a positive impact on soil quality. Wienhold et al. (2006) found that reduced tillage and the incidence of fallow combined with more diversified crop rotations improved soil function by supporting plant growth, providing a reservoir for essential plant nutrients, storing and purifying water, and providing a site for biological activity such as decomposing and recycling of plant and animal materials. Extended rotations involving forage crops may be more sustainable than current short-term agricultural practices (Randall, 2003).

Despite these benefits, the infrastructure developed and devoted to corn and soybean has resulted in a 500% increase in harvested area and 800% increase in soybean production between 1950 and 2003 (USDA-NASS, 2004). The dominant agricultural land use throughout the northern Corn-Soybean Belt became a 2-yr corn and soybean rotation during the last half of the 20th century. During that same period, oat production declined 90%, and although hay production increased because of better yields, the land area devoted to it decreased more than 15% (Karlen et al., 2006). This occurred for several reasons including simplicity and similar equipment requirements as farm size increased, commodity programs that emphasized short-term profit, public and private research and development efforts devoted to genetic improvement of corn and soybean, and increased food and industrial uses for both corn and soybean oils and various by-products (Karlen, 2004). It also coincided with major changes in the livestock industry that decreased demand for oat and alfalfa.

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In 1965, a group of young crop scientists laid out plots at the College of Agriculture and Life Science's Lancaster Agricultural Research Station. In 1966, a multiple crop rotation experiment was established to evaluate which rotations were the most profitable and sustainable for farmers in this region. This experiment was a joint collaboration between the University of Wisconsin, Iowa State University, University of Illinois, and the University of Minnesota. The emphasis was on corn grain production. It was established to compare the benefits of growing corn continuously using commercial N fertilizer, with those of rotating corn with alfalfa; with alfalfa supplying the N.

Forty years later, the original researchers have since retired, but the plots are still yielding data for what has become one of the longest running rotation studies in the U.S. To our knowledge, this is the only long term rotation experiment of its kind, making it not only unique but extremely valuable in the information that it can provide. The objective of this paper was to determine the effect of crop rotation and applied N on first phase corn grain yield in corn-soybean rotations and selected extended rotations.

MATERIALS AND METHODS

A long-term crop rotation study located in southwestern Wisconsin at the University of Wisconsin Agricultural Research Station near Lancaster, WI (42°51' N, 90°43' W)] was originally established to evaluate crop rotation and N fertilization rate effects on crop yield and soil N mineralization, retention, and availability (Vanotti and Bundy, 1994, 1995). The study was located on Rozetta (fine-silty, mixed, superactive, mesic Typic Hapludalfs) soil, which consists of very deep well-drained soils formed in loess on uplands (USDA-SCS, 1961). Permeability is moderate, and slopes range from 0 to 25%. Mean annual temperature and precipitation are 51 °F and 36 inches, respectively. The site is located in the driftless area of Major Land Resource Area (MLRA) 105 found in southwest Wisconsin, southeast Minnesota, northeast Iowa, and northwest Illinois (USDA-SCS, 1981). The deep, rugged valleys and karst topography that characterize this 36.3 million acres region were carved into the sedimentary bedrock of a Paleozoic plateau by glacial runoff. The productive silt loam and loam soils were formed primarily from a deep loess layer overlying limestone, dolomite, sandstone, and shale bedrock (Prior, 1991). The steeply sloping land has very high erosion potential if not properly managed. Crop rotations, especially those with high residue production and including perennial crops like alfalfa, are important for comprehensive soil and crop management programs within this region (Karlen et al., 2006).

To accommodate all possible phases of the rotations and four fertilizer treatments, 168 plots (6.1 by 9.1 m) were established in 1966 in a randomized complete block in a split-plot design with two replications of 21 treatments to test the rotation effect by having each phase of every rotation represented each year. Thus, for continuous corn (CC), there were one plot within each statistical block, and for corn-soybean (CS) there was one corn plot and one soybean plot within each block. The crop sequence plots were split to accommodate four N rate treatments. From 1967 to 1976, N rates were 0, 75, 150, and 300 lb N A^{-1}, but since 1977, the annual rates have been 0, 50, 100, and 200 lb N A^{-1} for corn only (Table 1). N fertilizer treatments were applied in spring as ammonium nitrate (NH_4NO_3). Rotation treatments have changed over time (Table 1). Tillage has varied over time. Soil fertility samples were collected and analyzed every 3 yr, and uniform rates of P and K fertilizers were applied as needed to maintain optimum to high soil-test levels. Herbicides and cultivation were used for weed control as needed. Cultivars varied over time but were always improved selections developed for the region. The alfalfa, whether seeded alone or with oat, has not been harvested during the seeding year following oat harvest. For rotations with 1-yr alfalfa, the alfalfa was killed during the fall of the same year using appropriate herbicides or prior to 1999 the alfalfa was plowed under. For rotations with 2- or 3-yr of alfalfa, two or three harvests were taken depending on if it was a direct seeding year or established prior with oats, respectively.

Table 1. Crop rotations and nitrogen rates at Lancaster, Wisconsin used to evaluate the influence of crop rotation and nitrogen on the rotation effect of first year corn.†

1966-1976	1977-1986	1987-2004
Crop Rotation Treatments		
CC	CC	CC
CSCOaA	CSCOaA	CSCOaA
CCCOaA	CCCAA	CCCAA
CCOaAA	CCOaAA	CCOaAA
COaAAA	CCAA	CA
COaAAA	CCAA	CS
COaAAA	AA	
Nitrogen Treatments (lb N A^{-1})		
0	0	0
75	50	50
150	100	100
300	200	200

† C, corn; S, soybean; Oa, oat with alfalfa seeding; A, alfalfa.

The Lancaster cropping systems study is comprised of multiple crop rotations that take varying amounts of time to complete a rotation sequence. For example, CC takes 1 yr, CS takes 2 years, and CSCOaA takes 5 yrs (Table 1). However, the traditional analysis using years can be expanded to analyze both spatial and temporal trends based on the average yields produced in the period it took to accomplish the cycle. By doing this, we can see how the rotations preformed when they returned to the same piece of ground allowing data analysis across both time and space. Hence, we analyzed the data in groups of either 2- or 5-yrs depending on the length of the rotation cycle using CC as our control.

RESULTS AND DISCUSSION

Regression slopes of each phase of corn within each rotation sequence were evaluated to determine the long-term effects of various crop rotations and different N fertilization rates on grain yield. We compared each regression slope to zero to determine if over time the rotation treatments were improving or deteriorating, and to each other to determine if the relative slopes of each treatment are different (Fig. 2).

5-yr Rotations – First Corn Phase (1970 – 2004)

Corn grain yields increased from 1.1 to 1.6 bu A^{-1} yr^{-1} with increasing N rates (0 and 200 lb N A^{-1}, respectively) for corn that was rotated (Table 2). Relative yield trends for continuous corn did not improve over time no matter the N rate. Thus, there was no yield gain with adopting improved hybrids during the 35-yr of this study. This suggests two things, either hybrids have not improved since 1970, or that improved hybrids have kept continuous corn yield trends from declining over time. Currently, with the rapid turnover of hybrids there is no way to answer this question.

Rotating corn significantly improved corn grain yield over time for the first phase of corn when compared to CC (Table 2). For the 0 lb N A^{-1} treatment, grain yield for *C*CCAA, *C*COaAA, and *C*SCOaA rotations improved 1.2 to 1.3 bu A^{-1} yr^{-1}, respectively. In the 50 lb N A^{-1} treatment where N was applied but limiting, *C*CCAA, *C*COaAA, and *C*SCOaA improved grain yield by 1.1 to 1.2 bu A^{-1} yr^{-1}, respectively. For the 100 lb N A^{-1} treatment, *C*CCAA, *C*COaAA, and *C*SCOaA improved grain yield 1.4 to 1.5 bu A^{-1} yr^{-1}, respectively. Overall, within a diversified crop rotation and with adequate N (200 lb N A^{-1}), corn yields improved by 1.6 bu A^{-1} yr^{-1}or 1.4 % yr^{-1}, which is similar to the national average (USDA-NASS, 2006).

There was no difference in slope for the first phase of corn when comparing the 2, 3, and 4-crop rotation sequences at each N rate (Table 2). These results suggest as long as the previous crop is not corn, each rotation sequence in this study is equally effective in breaking the yield depression caused by monoculture.

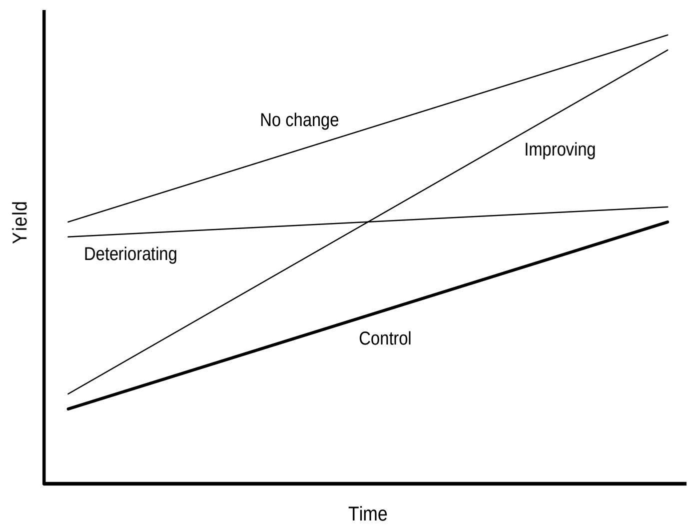

Fig. 2. Theoretical changes over time in cropping systems relative to the control cropping system.

2-yr Rotations (1989 – 2004)

Through 16 years (eight 2-yr cycles) CC grain yield at all N-rate levels was not affected over time and thus did not improve or deteriorate (Table 3). Corn grain yield in the CS rotation at 0 lb N A^{-1} decreased by 3 bu A^{-1} yr^{-1}. A similar trend was found for the CA rotation. Rotating corn with a legume improves corn grain yield over time only when additional N is added to the system.

5- vs. 2-yr Rotations (1990 – 2004)

A comparison was made of both the 5-yr rotations with the 2-yr rotations from 1990 to 2004, on a 5 yr cycle. The slopes of the rotations at each of the N rates are not significantly different from a zero slope, except for the decreasing slopes of CA and CS rotations at 0 lb N A^{-1} (Table 4). Since 1990, in the 0 lb N A^{-1} treatment, grain yields have actually declined by 2.5 and 2.8 bu A^{-1} yr^{-1}for the CA and CS rotations, respectively. For the 50 lb N A^{-1} treatment, the CS rotation decrease grain yields over time by 2.5 and 2.7 bu A^{-1} yr^{-1}when compared to the *C*CCAA and *C*COaAA rotations, respectively (Table 5). For the 100 lb N A^{-1} treatment, the CC rotation decrease grain yields over time by 2.5 bu A^{-1} yr^{-1}when compared to the *C*CCAA rotation. Since 1990 in the 200 lb N A^{-1} treatment, the CC rotation decreased grain yields over time by 2.6 and 2.5 bu A^{-1} yr^{-1}when compared to the *C*CCAA and *C*SCOaA rotations, respectively.

Based on these results, time (2+ yr) along with rotation were required between corn crops to improve corn grain yields. We agree with Randall (2003) and Karlen et al. (2006) that extended rotations involving forage crops may be more sustainable than current short-term agricultural practices. However, according to Karlen et al. (2006) without the support of federal incentive programs such as the Conservation Security Program or other public and private research and development efforts, markets and uses for forage-based products developed to promote economic and environmental sustainability, farmers will hesitate to adopt more sustainable practices.

CONCLUSION

Corn grain yield response data show that for extended crop rotations an alfalfa crop supplied most of the N required by the first phase of corn that improved over time. For the second phase of corn a lower but still substantial amount of the total N requirement was supplied from the previous alfalfa crop, however, additional N was needed in order to improve corn grain yields over time. With increasing years of corn following alfalfa, the differences in corn grain yield trends between rotated and continuous corn diminished. An application of 200 lb N A^{-1} was needed for grain yield improvement over time. The net effect of legumes in improving corn grain yield trends of subsequent corn was not evident for corn that was annually rotated (CA and CS). If no N is added, CA and CS appeared to depress corn grain yields with time. A single legume crop yr was only beneficial in maintaining corn yields over time if nitrogen was added to the system. When all rotations were compared (1990 to 2004), corn grain yields trends of 5-yr crop rotations were significantly better where no N was added and additional N was required for the 2-yr rotations to eliminate this difference. Our data show a long-term corn grain yield advantage of extended rotations when compared to 2-yr rotations and continuous corn. Nitrogen plays a major role in maintaining and improving corn grain yields in the absence of crop rotation. The addition of N removed the corn grain yield trend differences with time among crop rotation-phase treatments when CC was compared to the first phase of corn in 5-yr rotations. These results support the argument that extended rotations involving forage crops may be more sustainable than current short-term agricultural practices, because time (2+ yr) along with rotation and nitrogen were required to improve corn grain yields. However, without proper incentives like the Conservation Security Program, farmers may hesitate to adopt more sustainable practices.

REFERENCES

Dick, W.A., D.M. Van Doren, G.N. Triplett, and J.E. Henry. 1986. Influence of long-term tillage and rotation combinations on crop yields and selected soil parameters. Res. Bull. 1180. Ohio Agric. Res. and Dev. Cent., The Ohio State Univ., Columbus.

Higgs, R.L., A.E. Peterson, and W.H. Paulson. 1990. Crop rotation: Sustainable and profitable. J. Soil Water Conserv. 45:68-70.

Karlen, D.L. 2004. Cropping systems: Rain-fed maize-soybean rotations of North America. p. 358-362. *In*: R.M. Goodman (ed.). Encyclopedia of plant and crop science. Marcel Dekker, Inc., New York.

Karlen, D.L., E.G. Hurley, S.S. Andrews, C.A. Cambardella, D.W. Meek, M.D. Duffy, and A.P. Mallarino. 2006. Crop rotation effects on soil quality at three Northern Corn/Soybean Belt locations. Agron. J. 98:484-495.

Karlen, D.L., G.E. Varvel, D.G. Bullock, and R.M. Cruse. 1994. Crop rotations for the 21st century. Adv. Agron. 53:1-45.

Katsvairo, T.W., and W.J. Cox. 2000a. Economics of cropping systems featuring different rotations, tillage, and management. Agron. J. 92:485-493.

Katsvairo, T.W., and W.J. Cox. 2000b. Tillage x rotation x management interactions in corn. Agron. J. 92:493-500.

Magdoff, F., and H. van Es. 2000. Crop rotations. p. 99-108 *In*: Building soils for better crops. 2nd ed. Sustainable Agric. Publ., Univ. of Vermont, Burlington, VT.

Mannering, J.V., and D.R. Griffith. 1981. Value of crop rotation under various tillage systems. Agron. Guide AY-230. Coop. Ext. Serv., Purdue Univ., West Lafayette, IN.

Peterson, T.A., and G.E. Varvel. 1989a. Crop yield as affected by rotation and nitrogen rate: I. Soybean. Agron. J. 81:727-731.

Peterson, T.A., and G.E. Varvel. 1989b. Crop yield as affected by rotation and nitrogen rate: III. Corn. Agron. J. 81:735-738.

Porter, P.M., J.G. Lauer, W.E. Lueschen, J.H. Ford, T.R. Hoverstad, E.S. Oplinger, and R.K. Crookston. 1997. Environment affects the corn and soybean rotation effect. Agron. J. 89:441-448.

Prior, J.C. 1991. Landforms of Iowa. University of Iowa Press, Iowa City.

Raimbault, B.A., and T.J. Vyn. 1991. Crop rotation and tillage effects on corn growth and soil structural stability. Agron. J. 83:979-985.

Randall, G.W. 2003. Present-day agriculture in southern Minnesota-is it sustainable? [Online]. Available at http://sroc.coafes.umn.edu/Soils/Recent%20Publications%20and%20 Abstracts/Present-Day%20Agriculture.pdf (verified 11 July 2006). Univ. of Minnesota, Southern Res. and Outreach Cent., Waseca.

[USDA-NASS] USDA National Agricultural Statistics Service. 2004. Historical track records [Online]. Available at www.usda.gov/nass/pubs/trackrec/croptr04.pdf (verified 1 May 2006). USDA-NASS, Washington, DC.

[USDA-SCS] USDA Soil Conservation Service. 1961. Soil Survey of Grant County Wisconsin. USDA-NRCS in cooperation with the Wisconsin Agric. Exp. Stn., Madison, WI.

[USDA-SCS] USDA Soil Conservation Service. 1981. Land resource regions and major land resource areas of the United States. Agric. Handb. 296. U.S. Gov. Printing Office, Washington, DC.

Vanotti, M.B., and L.G. Bundy. 1994. Corn nitrogen recommendations based on yield response data. J. Prod. Agric. 7:249-256.

Vanotti, M.B., and L.G. Bundy. 1995. Soybean effect on soil nitrogen availability in crop rotations. Agron. J. 86:676-680.

Wienhold, B.J., J.L. Pikul, Jr., M.A. Liebig, M.M. Mikha, G.E. Varvel, J.W. Doran, and S.S. Andrews. 2006. Cropping system effects on soil quality in the Great Plains: Synthesis from a regional project. Renewable Agric. Food Syst. 21:49-59.

White, D.C., J.B. Braden, and R.H. Hornbaker. 1994. Economics of sustainable agriculture. p. 229-260. *In*: J.L. Hatfield and D.L. Karlen (ed.). Sustainable agricultural systems. CRC Press, Boca Raton, FL.

Table 2. Corn grain yield rate of change for the first phase of corn (bu A^{-1} yr^{-1}) of 5-yr rotations in various N rate (lb N A^{-1}) treatments at Lancaster, WI from 1970 to 2004 (seven 5-yr cycles).

	lb N A^{-1}			
Rotation	**0**	**50**	**100**	**200**
	bu A^{-1} yr^{-1}			
CC	**NS**	**NS**	**NS**	**†**
***C*CCAA**	**1.2****	**1.1****	**1.4****	**1.6****
***C*COaAA**	**1.3****	**1.2****	**1.5****	**1.6*****
***C*SCOaA**	**1.2****	**1.1****	**1.4*****	**1.6*****

†, *, **, * Significant at the 0.10, 0.05, 0.01, and 0.001 levels, respectively**

Table 3. Corn grain yield rate of change for corn (bu A^{-1} yr^{-1}) of 2-yr rotations in various N rate (lb N A^{-1}) treatments at Lancaster, WI from 1989 to 2004 (eight 2-yr cycles).

	lb N A^{-1}			
Rotation	**0**	**50**	**100**	**200**
			bu A^{-1} yr^{-1}	
CC	NS	NS	NS	NS
CA	†	NS	NS	NS
CS	-3.0*	NS	NS	NS

†, *, **, *** Significant at the 0.10, 0.05, 0.01, and 0.001 levels, respectively

Table 4. Corn grain yield rate of change for corn (bu A^{-1} yr^{-1}) of 5-yr and 2-yr rotations in various N rate (lb N A^{-1}) treatments at Lancaster, WI from 1990 to 2004 (three 5-yr cycles).

	lb N A^{-1}			
Rotation	**0**	**50**	**100**	**200**
			bu A^{-1} yr^{-1}	
CC	NS	NS	NS	NS
CA	-2.5*	NS	NS	NS
CS	-2.8*	†	NS	NS
*C*CCAA	NS	NS	NS	NS
*C*COaAA	NS	NS	NS	NS
*C*SCOaA	NS	NS	NS	NS

†, *, **, *** Significant at the 0.10, 0.05, 0.01, and 0.001 levels, respectively

Table 5. Corn grain yield rate of change contrasts for corn (bu A^{-1} yr^{-1}) in 5-yr (first phase) and 2-yr rotations in various N rate (lb N A^{-1}) treatments at Lancaster, WI from 1990 to 2004 (three 5-yr cycles).

	lb N A^{-1}			
Rotation	**0**	**50**	**100**	**200**
			bu A^{-1} yr^{-1}	
CC vs. CA	3.8***	NS	NS	NS
CC vs. CS	4.1***	NS	NS	NS
CC vs. *C*CCAA	NS	NS	-2.5*	-2.6*
CC vs. *C*COaAA	NS	NS	NS	NS
CC vs. *C*SCOaA	NS	NS	NS	-2.5*
CA vs. CS	NS	NS	NS	NS
CA vs. *C*CCAA	-3.0***	NS	NS	NS
CA vs. *C*COaAA	-2.7*	†	NS	NS
CA vs. *C*SCOaA	-2.7*	NS	NS	NS
CS vs. *C*CCAA	-3.3***	-2.5*	NS	NS
CS vs. *C*COaAA	-3.0***	-2.7*	NS	NS
CS vs. *C*SCOaA	-2.9***	NS	NS	NS

†, *, **, *** Significant at the 0.10, 0.05, 0.01, and 0.001 levels, respectively

2006 WISCONSIN PESTICIDE USE SURVEY

Jeff Postle [1/]

In 2006, the Wisconsin Agriculture Statistics Service (WASS) and the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) completed a major pesticide use survey for the 2003-2005 growing seasons. This survey was conducted and reported so that it can be compared to previous pesticide use surveys (major surveys in 1985, 1990 and 1996 and annual summaries in 1991-2006). DATCP intends to conduct a major pesticide use survey approximately every 5 to 10 years so that long term trends in pesticide use in Wisconsin can be identified and studied. The survey report contains a wealth of information on pesticide use in Wisconsin.

The survey was conducted by using personal interviews with farm operators. The various crops surveyed included field crops (corn, soybeans, barley, potatoes and oats), fruits (apples and tart cherries), and vegetables (fresh market cabbage, processing carrots, processing cucumbers, processing green peas, processing snap beans, processing sweet corn and fresh market sweet corn).

The results of the survey show that pesticide use remains an integral part of crop production in Wisconsin. A high percentage of the acreage of the crops surveyed receives herbicide applications. The prevalence of insecticide and fungicide use varies considerably from crop to crop. The following table shows this information in more detail.

Acres Planted and Pesticide Use on Selected Crops, Wisconsin, 2004-2005

Crop	Acres planted (X1000)	Acres receiving herbicides (percent)	Acres receiving insecticides (percent)	Acres receiving fungicides (percent)
Corn	3,800	97	22	--
Soybeans	1,610	98	11	--
Potatoes	68.0	99	97	99
Sweet corn †	80.7	87	53	27
Snap beans †	76.0	89	83	51

† For processing.

One new feature that started with the 1996 report is the comparison over time of the use of selected pesticides. This information is useful for observing which pesticides are increasing in popularity and which ones are decreasing. For example, the survey results show that the use of the corn herbicides atrazine and acetochlor remains fairly constant, dicamba (Banvel) use is decreasing and glyphosate use is increasing. The following graph shows some of these trends. (Note: corn acres planted varies by year).

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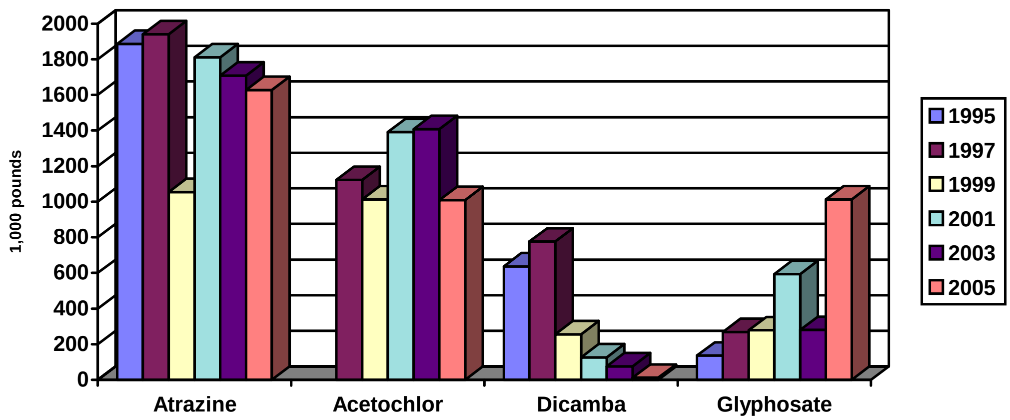

Historic Use of Selected Corn Herbicides
(total applied)

Another set of comparisons in this report is between pesticide use in Wisconsin and other nearby states. This information points out some interesting differences between crop production and pesticide use in Wisconsin versus our neighbors that are more oriented to cash grain production. Some of these other states produce much larger quantities of corn and soybeans than Wisconsin and use correspondingly greater quantities of pesticides.

2005 Corn Production (1,000 acres) and Herbicide Use (1,000 pounds) in Six Midwestern States.

State	Corn acres planted	Atrazine	S-Metolachlor (Dual)	Glyphosate (iso salt)
Wisconsin	3,800	1,627	1,677	1,013
Illinois	12,100	13,729	5,005	1,176
Indiana	5,900	5,670	3,001	772
Iowa	12,800	8,276	4,335	2,230
Michigan	2,300	1,952	676	699
Minnesota	7,300	1,660	681	2,853

Copies of the 2006 Wisconsin Pesticide Use Report are available from the Wisconsin Agricultural Statistics Service, P.O. Box 8934, Madison, WI 53708-8934. Telephone 608/224-4848. The report is also available at http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Miscellaneous/pest_use_06.pdf

EFFECTIVE MANAGEMENT OF WEEDS IN NO-TILL

Mark M. Loux [1/]

No-tillage conditions result in greater diversity in the weed species and weed life cycles that occur in corn and soybean production, compared with conventional and minimum tillage systems. This diversity can be challenging to manage, especially when growers attempt to oversimplify herbicide programs in hopes of cutting costs. Successfully managing weeds in no-till can be accomplished with relatively minor changes in herbicide programs, or it can require a substantial change in strategy, depending upon the nature of the weed population. Failure to use the appropriate strategy, or to adapt new strategies in response to weed population shifts, can result in poor weed control and further increases in populations. For example, some Roundup Ready soybean growers in Ohio have omitted preplant burndown treatments from their weed management programs, which have resulted in increased populations of winter annual weeds and dandelions, and problems with control of early-emerging summer annual weeds such as lambsquarters and giant ragweed. This approach has also contributed to over-reliance on glyphosate, and has been a primary cause of glyphosate resistance in horseweed (marestail).

Glyphosate and Roundup Ready crops are extremely effective tools for management of weeds in no-till, but poor management of these tools by growers can reduce their utility. The ability of glyphosate to control a broad spectrum of weeds, even large weeds when necessary, does not change the need for the following components in no-till soybean weed management programs: (1) either a fall or spring preplant burndown treatment to control winter weeds, and early-emerging summer annuals; (2) an early postemergence glyphosate application when weeds are 4 to 8 inches tall; and (3) a second postemergence application as necessary to control late-emerging weeds or those not completely controlled with the first application. Producers who integrate glyphosate with other herbicides, as in the inclusion of 2,4-D ester and residual herbicides in fall or preplant treatments, may improve control of certain weeds, reduce the need for a second postemergence application, and reduce selection for glyphosate resistance. The remainder of this article discusses strategies for management of the various weed life cycles that occur in no-till production, and serves to reinforce these principles.

Winter Annual Weeds

Winter annual weeds, such as common chickweed, purple deadnettle, and cressleaf groundsel, emerge primarily in late summer through fall, although some winter annual species can emerge in the spring also. The over-wintering winter annual populations are most problematic in crop production, since they develop the dense growth in spring that interferes with crop establishment. Dense stands of winter annual weeds can prevent soil

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from drying out and warming up, harbor insect populations, increase soybean cyst nematode populations, and interfere with crop planting and early-season crop growth. Most winter annuals flower and go to seed in late spring, so their major impact on crops occurs early in the growing season. The life cycle of one winter annual, horseweed (marestail), persists long enough for it to interfere with crop growth well into the growing season. The seed of winter annual weeds generally lacks dormancy, and allowing a dense stand of winter annual weeds to go to seed in spring can result in an immediate increase in populations the following fall.

The major goal of winter annual weed management should be to control them prior to crop planting and early enough in spring to prevent seed production and minimize their impact on soil drying and crop establishment. This can be accomplished by application of herbicides in the fall or spring. Fall herbicide treatments are overall more effective for winter annual weed control. Cold weather and dense populations in spring can result in difficulty obtaining adequate control and dessication of plants soon enough before planting.

Biennial Weeds

Biennial weeds have a 2-year life cycle, and well-established second-year plants are the major problem in no-till crop production. Weed species with this life cycle include wild carrot, poison hemlock, and burdock. Unlike winter annuals, which end their life cycle in late spring, second-year biennials do not end their life cycle until late summer or fall. Second-year plants can therefore interfere with crop establishment and growth throughout much of the growing season. Biennials are most easily controlled by herbicide application in the fall of the first year of growth, when they are small. Plants that have over-wintered are much more robust, growing from a well-established taproot, and are generally less sensitive to herbicides. When necessary, spring herbicide treatments should be applied early when plants are small, and should include several herbicides to ensure control. Growers who choose to omit preplant herbicide treatments from their no-till programs tend to have problems controlling biennial weeds.

Cool-season Perennial Weeds

Cool-season perennial weeds, such as Canada thistle, quackgrass, and dandelion, are not extremely difficult to manage in no-till systems where Roundup Ready crops are used. When not managed appropriately, however, they can greatly affect crop establishment, and interfere with crop growth well into the growing season. Cool-season perennials can emerge prior to planting in Ohio, interfere with crops until late spring or early summer, when they flower and go to seed, and then senesce. Growth resumes in late summer or fall and continues until a hard freeze in late fall. The adoption of Roundup Ready crops has resulted in an overall decrease in the number and density of infestations of Canada thistle and quackgrass in Ohio. Both weeds are often effectively controlled by sequential applications of glyphosate, even when growers omit preplant herbicide treatments in no-till.

Dandelion has become extremely problematic in no-till crop production in Ohio, even though growers have effective tools to manage it. Fall herbicide treatments are by far the most effective tool for management of dandelion, especially for very dense populations. Dandelion is not easily controlled in the spring, but continuous use of effective preplant burndown treatments can keep it under control, especially when combined with residual herbicides, and followed with an effective postemergence treatment. Dandelion becomes more difficult to manage when any of these are omitted, and growers who omit the preplant treatment and try to get by with multiple postemergence glyphosate applications have observed the greatest increase in dandelion populations. Dandelions flower and senesce relatively early in the spring in Ohio, and applying herbicides after this has occurred results in greatly reduced control. In addition, dandelion seeds lack dormancy, and seed produced in spring are the source of seedling dandelions later that same spring. Including residual herbicides in the preplant burndown treatment can provide control of seedling dandelions, as can postemergence treatments. Effective postemergence treatments can also help control plants that regrow following preplant burndown treatments, but usually do not provide adequate control where the preplant treatment was omitted or was largely ineffective. Where herbicides are applied in the fall for dandelion control, it is possible to omit the preplant burndown treatment the following spring and rely on postemergence glyphosate treatments for control.

Warm-season Perennial Weeds

Warm-season perennial weeds, such as pokeweed, hemp dogbane, and horsenettle, are well-adapted to no-till systems. These weeds emerge in late-spring or early summer, typically after crop emergence, and persist until late summer or early fall. Postemergence herbicides are really the only option for control of warm-season perennials. Postemergence use of glyphosate in Roundup Ready soybeans has reduced populations of many warm-season perennials. Glyphosate is most effective for reducing populations of perennials when applied at high rates and in two postemergence applications instead of just one. In spite of its apparent effectiveness on pokeweed in university studies, populations of this weed have been on the increase in corn and soybeans in the eastern cornbelt. Growers may be expecting to obtain adequate control with lower labeled rates of glyphosate, and with just one postemergence application. Where growers omit a preplant burndown treatment, and they are forced to make the first postemergence glyphosate application soon after planting, it is possible that pokeweed has not emerged or is too small to be effectively controlled. Inadequate spray coverage on larger pokeweed plants may also be one reason for poor control.

Summer Annual Weeds

Summer annual weeds, such as ragweeds, velvetleaf, foxtails, and common lambsquarters, are present in all tillage systems, but some are better adapted to no-till than others. There is a tendency for populations of large-seeded broadleaf weeds to decrease under no-till conditions, but this does not necessarily mean that control of these weeds can be deemphasized. For example, giant ragweed populations can decrease under no-till conditions, but the extended duration of emergence of this weed and its extreme competitiveness with the crop demand an aggressive management strategy regardless of the population density. No-till conditions and the presence of surface residue can promote a more extended duration of emergence of foxtails and other small-seeded weeds, which increase the need for multiple postemergence applications or a combination of preemergence and postemergence herbicides to control late-emerging weeds. Aside from this, the major difference between no-till and tilled systems is the method of controlling summer annual weeds that emerge before planting – herbicides vs. tillage. A combination of 2,4-D ester plus either glyphosate or Gramaxone is usually effective for control of emerged summer annuals prior to planting, and it is possible to accomplish this without the 2,4-D ester if absolutely necessary. Many growers have decided that a preplant burndown treatment is not essential, however, and they expect postemergence glyphosate treatments to control large, aged weeds that have been growing since early in spring. This approach has been a major source of poor control in Roundup Ready soybean fields, and has contributed to the development of glyphosate resistance. While early-emergers such as giant ragweed, lambsquarters, and marestail can be easily controlled with preplant burndown treatments of glyphosate plus 2,4-D ester, they can be extremely difficult to completely control with postemergence glyphosate applications in the absence of a preplant burndown. Research conducted by OSU and Purdue University has shown that it is impossible to obtain adequate control of glyphosate-resistant giant ragweed, unless the weed management program starts with a preplant herbicide treatment that includes 2,4-D ester.

WEED CHANGES AFTER EIGHT YEARS OF CONTINUOUS GLYPHOSATE USE

David E. Stoltenberg and Mark R. Jeschke [1]

Introduction

Glyphosate-resistant soybeans have been widely adopted by growers due to the benefits of broad-spectrum efficacy, reduced crop injury, and simplification of weed management. Glyphosate-resistant corn has expanded in use in recent growing seasons and as a result, glyphosate is increasingly being depended upon as the primary means of weed management in corn and soybean production.

The widespread use of this technology has produced concerns about the effect of continuous use of glyphosate on weed community composition and the development of new weed problems. The goal of this research was to determine the long-term weed management and agronomic risks in glyphosate-resistant corn and soybean as influenced by intensity of tillage and glyphosate use. Research was conducted at the University of Wisconsin from 1998 to 2006 to determine the long-term effects of primary tillage system and glyphosate use intensity on weed population dynamics in a glyphosate-resistant corn and soybean annual rotation.

Methods

Research was conducted at the University of Wisconsin Arlington Agricultural Research Station from 1998 through 2006. Six weed management treatments were compared in a corn-soybean annual rotation across three primary tillage systems: moldboard plow, chisel plow, and no-tillage (Table 1).

Table 1. Weed management treatments in a corn-soybean annual rotation from 1998-2006.

Treatment †	Soy: 1998, 2000, 2002, 2004, 2006	Corn: 1999, 2001, 2003, 2005
1	Glyphosate POST	Glyphosate POST
2	Glyphosate POST	Glyphosate POST + LPOST
3	Glyphosate POST	Glyphosate POST + Cultivation
4	Glyphosate POST	Non-Glyphosate
5	Non-Glyphosate	Non-Glyphosate
6	Residual grass herbicide PRE + Glyphosate POST	Residual grass herbicide PRE + Glyphosate POST

† PRE = preemergence, POST = postemergence, LPOST = late postemergence

Non-glyphosate treatments consisted of herbicide combinations for broad-spectrum weed control. Weed management treatments in no-tillage included glyphosate applied as a burn-down. The experimental design was a randomized complete block in a split-split-block arrangement with three replications. The main plots were factorial combinations of tillage and cropping sequence treatments (corn-soybean annual rotation shown only), and the subplot factors were weed management treatments.

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Soil type was Plano silt loam with pH 5.8 and 4.1% organic matter. Primary tillage was conducted during the fall of each year. The seedbed was prepared shortly before planting with a field cultivator/straight-tooth harrow in moldboard plow and chisel plow systems. Soybean was planted in 1998, 2000, 2002, 2004, and 2006, and corn was planted in 1999, 2001, 2003, and 2005. Glyphosate-resistant soybean was drilled in early May at 250,000 seeds/acre in rows spaced 7.5 inches apart. Glyphosate-resistant corn was planted in late April or early May at 32,000 seeds/acre in rows spaced 30 inches apart. For corn, 150 lb/acre N were applied pre-plant and 150 lb/acre 6-24-24 N-P_2O_5-K_2O was applied as starter fertilizer at planting. Corn and soybean were harvested by machine for grain yield.

Plots were maintained in the same location and received consistent treatments over the duration of the experiment. Plot size was 20-ft wide by 40-ft long. The soil weed seedbank was sampled each spring. Weed seeds were quantified from 30 soil cores taken from the upper 4 inches of the soil profile in each plot. Sixteen micro-plots (each 10 inches by 10 inches) were established within each plot for measuring weed plant density. Plant densities of each weed species were measured immediately prior to POST herbicide treatments, 4 weeks after POST treatment (WAT), 8 WAT, and prior to crop harvest. Plots were sub-sampled for weed shoot biomass prior to crop harvest.

Results

Thirty-three weed species were identified in this experiment from 1998 to 2006 (data not shown). Averaged over tillage systems, common lambsquarters, redroot pigweed, and giant foxtail were the most abundant species in the weed seedbank community from 1999 to 2005 (Table 2). Other species, particularly giant ragweed, shattercane, and large crabgrass increased in abundance in the seedbank over time. Common lambsquarters and giant foxtail were also the most abundant species over time in the plant community, based on weed density measurements at the time of POST treatments. In contrast, redroot pigweed abundance in the weed plant community decreased over time, whereas the abundance of giant ragweed, shattercane, and large crabgrass increased between 1999 and 2005. The most notable increase in the plant community was for giant ragweed.

Table 2. Weed species composition of the soil seedbank and plant community in 1999 and 2005.†

	Seedbank		Plant community	
Weed species	1999	2005	1999	2005
	% of total			
Common lambsquarters	70	65	33	34
Redroot pigweed	12	11	20	6
Giant foxtail	16	11	33	29
Velvetleaf	2	2	8	2
Shattercane	0	3	1	2
Giant ragweed	0	3	0	23
Large crabgrass	0	1	0	1
Other species	0	3	5	4

† The total number of viable weed seeds in the upper 4 inches of the soil profile was measured in April or May each year. Plant densities were measured prior to POST herbicide treatments. Data were averaged across tillage systems.

The total viable weed seedbank density was significantly affected by tillage system, weed management treatment, and year (Table 3). However, the total viable seedbank density decreased between 1998 and 2006 for most weed management treatments in each tillage system (Figure 1). Common lambsquarters seedbank density was similar across tillage systems and weed management treatments (Table 3), and either changed little or decreased between 1998 and 2006 (Fig. 1).

Table 3. Tillage, weed management, and year effects on the viable weed seedbank (1999-2006) and weed plant community (1998-2005) composition in an annual corn-soybean rotation. †

Weed community	Factor	Total weed species	Common lambsquarters	Redroot pigweed	Giant foxtail	Other broadleaves	Other grasses
		———————	———————	———————	*p*-value	———————	———————
Seedbank	Tillage	0.0382	NS ‡	NS	NS	0.0135	NS
	Weed mgmt	0.0015	NS	NS	<0.0001	0.0271	<0.0001
	Year	<0.0001	<0.0001	<0.0001	<0.0001	0.0409	<0.0001
Plant	Tillage	0.0024	0.0171	0.0428	NS	0.0097	NS
	Weed mgmt	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Year	NS	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

† The total number of viable weed seeds in the upper 4 inches of the soil profile was measured in April or May each year. Plant densities were measured prior to POST herbicide treatments.
‡ NS indicates not significant at $\alpha = 0.05$.

Total weed plant density at the time of POST treatments was significantly affected by tillage system (Table 3) and was typically less in moldboard plow than chisel plow or no-tillage systems (Figure 2). Weed management treatment also significantly affected total weed plant density at the time of POST treatments, with the greatest densities typically associated with the glyphosate POST treatment in corn and soybean (Treatment 1 in Table 1). However, most glyphosate-based weed management treatments were associated with a reduction in total weed density of 85% or more by late-season (Fig. 2).

Common lambsquarters plant density at the time of POST treatments was significantly affected by tillage system (Table 3) and was typically greater in moldboard plow and chisel plow systems than the no-tillage system in most years (Fig. 3). Common lambsquarters plant density at the time of POST treatment was also significantly affected by weed management treatment over time, but the relationship between density and weed management treatment was inconsistent. In contrast, weed management treatments were associated with a high level of efficacy on common lambsquarters, based on late-season plant densities. Across weed management treatments, reduction in common lambsquarters density between early and late season was 98, 88, and 82% or greater in moldboard plow, chisel plow, and no-tillage systems, respectively.

Although changes in weed density are commonly used to assess efficacy of weed management treatments, such measures may not reflect the impact of a few highly competitive weeds. In an effort to assess this aspect of weed community composition, we measured late-season shoot biomass of weeds before crop harvest. These late-season measurements showed that total weed shoot biomass per unit area was inversely related to the intensity of tillage, i.e. late-season weed shoot biomass was typically lowest in the moldboard plow system and greatest in the no-tillage system (Fig. 4). Total weed shoot biomass averaged 12 g m^{-2} in the moldboard plow system compared to 99 and 113 g m^{-2} in the chisel plow and no-tillage systems, respectively. Consistent with late-season common lambsquarters densities (Fig. 3), common lambsquarters contributed very little to late-season shoot dry biomass of the weed community, averaging less than 1 g m^{-2} across treatments (Fig. 4).

In contrast to common lambsquarters, giant ragweed and shattercane accounted for most of the late-season shoot biomass of the weed community (Fig. 5). Giant ragweed was not observed during the first 2 years of the experiment; however, populations quickly established beginning in year three (data not shown). Giant ragweed shoot biomass was the greatest in the chisel plow system and least in the moldboard plow system. The apparent greater affinity of giant ragweed for the chisel plow system relative to moldboard plow and no-tillage systems may be attributable to a greater proportion of giant ragweed seeds at optimal soil depths for germination, emergence, and early growth. Giant ragweed emergence rates have been found to be greatest at a seed burial depth of about 1 inch, although emergence can occur from as deep as 6 inches. Emergence rates are typically very low within the upper 0.5 inch of the soil profile, where a large proportion of the weed seedbank is found in no-tillage systems. Additionally, high rates of giant ragweed seed predation have been observed in no-tillage systems, making no-tillage a less favorable environment for giant ragweed proliferation.

In the chisel-plow system, late-season giant ragweed biomass was typically greatest in treatments that included a non-glyphosate component (Treatments 4 and 5 in Table 1) in years five to seven of the experiment (Fig. 5). Modifications in non-glyphosate treatment chemistries during this time were successful to some extent in reducing giant ragweed biomass in these treatments. In addition, giant ragweed shoot biomass increased during years six to eight for treatments that included glyphosate POST only for post-emergence weed management in corn and soybean (Table 1, Treatments 1 and 6) in both chisel plow and no-tillage systems. In contrast, extended periods of efficacy associated with treatments that included glyphosate LPOST or cultivation (Treatments 2 and 3 in Table 1, respectively) were associated with low levels of giant ragweed shoot biomass over time.

Late-season shoot biomass levels of shattercane were the greatest of any weed species in the experiment; shattercane was a particularly difficult management problem in the no-tillage system (Fig. 5). Shattercane shoot biomass averaged 1, 10, and 61 g m^{-2} in the moldboard plow, chisel plow, and no-tillage systems, respectively. Among weed management treatments, the patterns of shattercane biomass were similar to those for giant ragweed. Shattercane biomass levels increased most notably in the chisel plow and no-tillage systems where glyphosate POST in soybean was rotated annually with a non-glyphosate herbicide program in corn (Treatment 4 in Table 1) and where non-glyphosate herbicides only were used (Treatment 5 in Table 1). Also in the no-tillage system, shattercane was a management problem during years six to eight for treatments that included glyphosate POST only for postemergence weed management in corn and soybean (Treatments 1 and 6 in Table 1).

Conclusions

Changes in the species composition of weed communities were relatively minor over 8 years in glyphosate-based treatments, with common lambsquarters and giant foxtail persisting as the most abundant weed species. However, management efficacy of common lambsquarters remained at a high level over time. The most rapid changes in the weed community were associated with the non-glyphosate herbicide treatments, and were largely due to increases in giant ragweed and shattercane populations. Although only minor changes in weed species abundance occurred in glyphosate-based treatments, an extended emergence period may be a key mechanism by which weed populations persisted or increased over time.

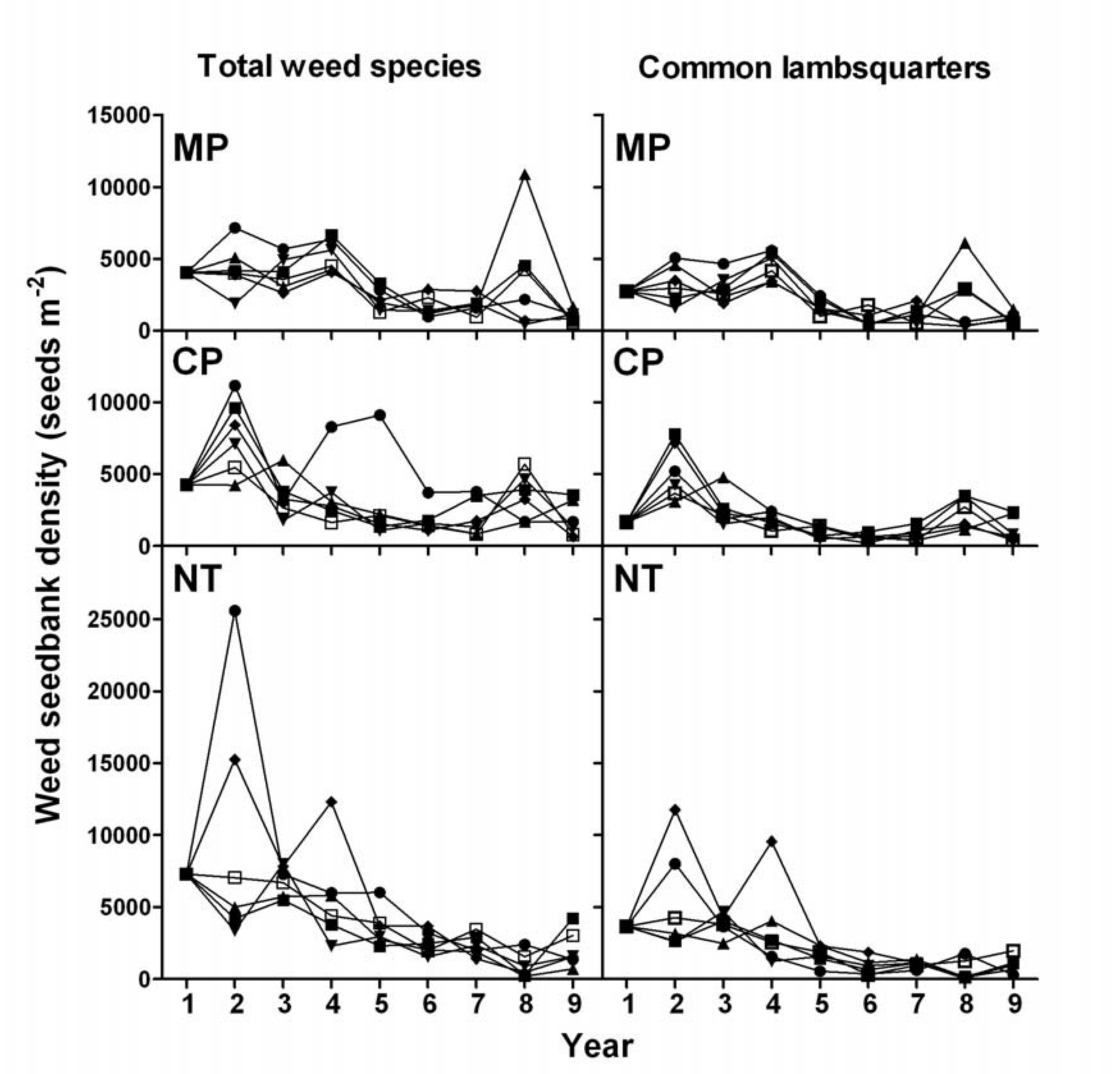

Figure 1. Viable seedbank density for total weed species and common lambsquarters from 1998-2006 as affected by moldboard plow (MP), chisel plow (CP), and no-tillage (NT) systems and weed management treatment in an annual corn-soybean rotation. Soybean was planted in 1998, 2000, 2002, 2004, and 2006; corn was planted in 1999, 2001, 2003, and 2005. Weed management treatments were 1) glyphosate POST in corn and soybean (■), 2) glyphosate POST and LPOST in corn and glyphosate POST in soybean (▲), 3) glyphosate POST plus inter-row cultivation in corn, and glyphosate POST in soybean (▼), 4) glyphosate POST in soybean rotated annually with a non-glyphosate herbicide program in corn (◆), 5) a non-glyphosate herbicide program in both corn and soybean (●), and 6) a PRE grass herbicide followed by glyphosate POST in both corn and soybean (□). Weed management treatments in NT included glyphosate applied as a burn-down.

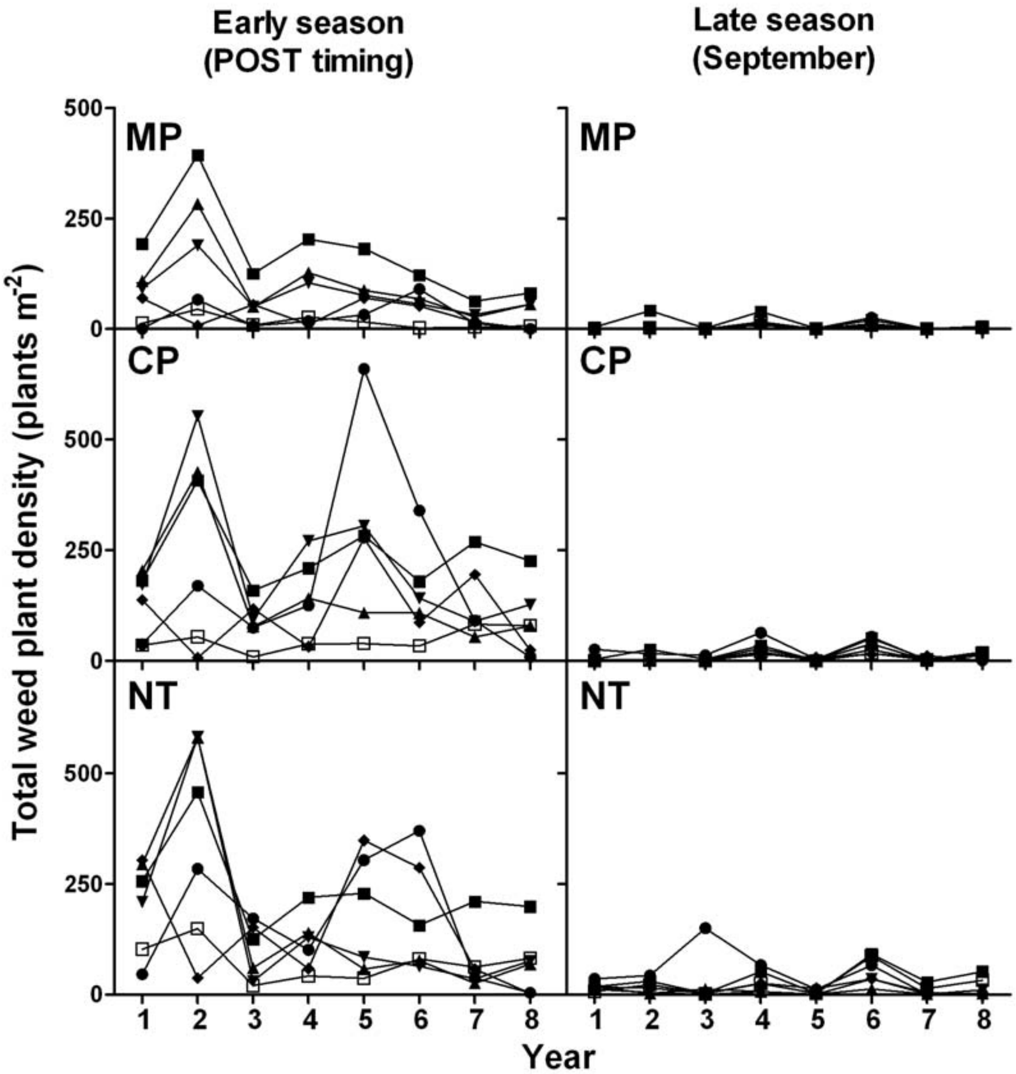

Figure 2. Total weed plant density early season (at the time of POST herbicide treatments) and late season from 1998-2005 as affected by moldboard plow (MP), chisel plow (CP), and no-tillage (NT) systems and weed management treatment in an annual corn-soybean rotation. Soybean was planted in 1998, 2000, 2002, and 2004; corn was planted in 1999, 2001, 2003, and 2005. Weed management treatments were 1) glyphosate POST in corn and soybean (■), 2) glyphosate POST and LPOST in corn and glyphosate POST in soybean (▲), 3) glyphosate POST plus inter-row cultivation in corn, and glyphosate POST in soybean (▼), 4) glyphosate POST in soybean rotated annually with a non-glyphosate herbicide program in corn (◆), 5) a non-glyphosate herbicide program in both corn and soybean (●), and 6) a PRE grass herbicide followed by glyphosate POST in both corn and soybean (□). Weed management treatments in NT included glyphosate applied as a burn-down.

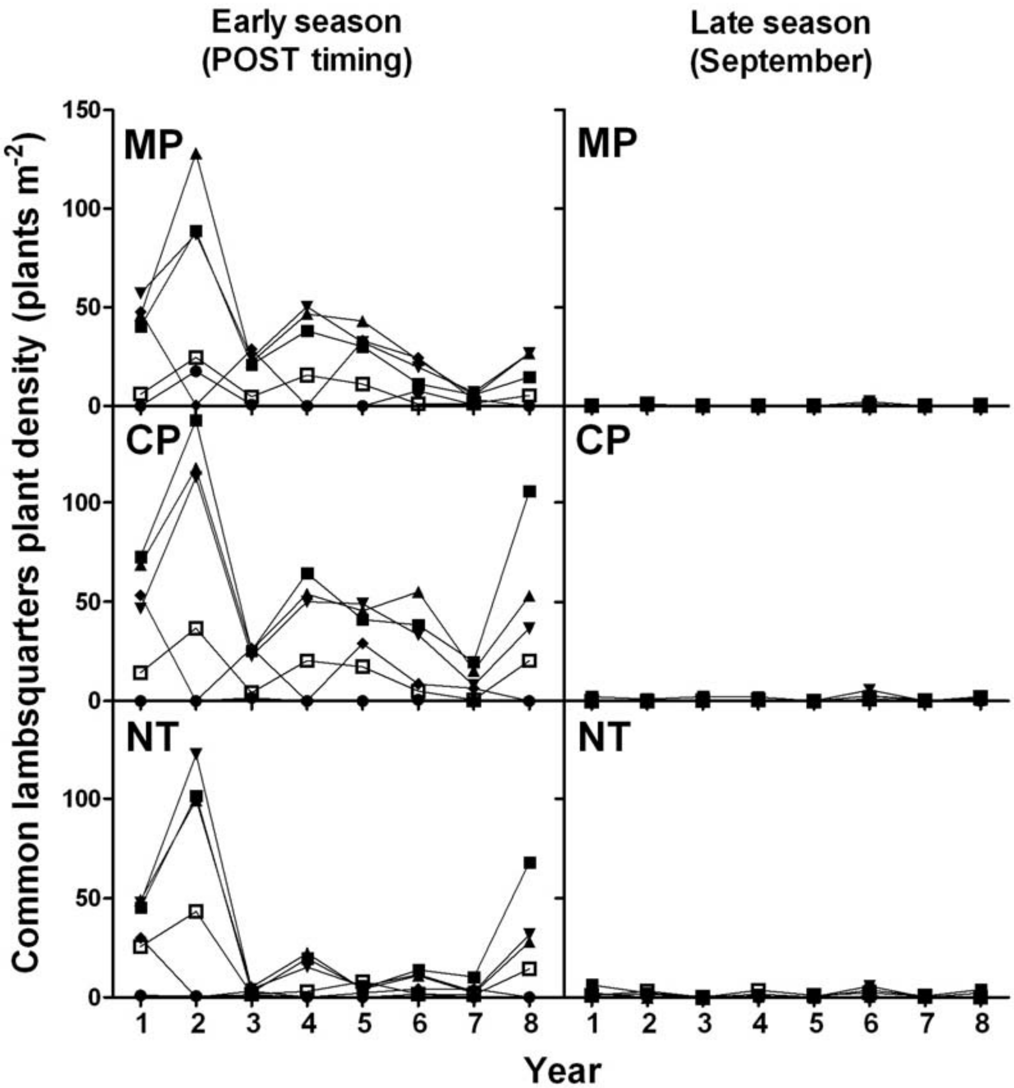

Figure 3. Common lambsquarters plant density early season (at the time of POST herbicide treatments) and late season from 1998-2005 as affected by moldboard plow (MP), chisel plow (CP), and no-tillage (NT) systems and weed management treatment in an annual corn-soybean rotation. Soybean was planted in 1998, 2000, 2002, and 2004; corn was planted in 1999, 2001, 2003, and 2005. Weed management treatments were 1) glyphosate POST in corn and soybean (■), 2) glyphosate POST and LPOST in corn and glyphosate POST in soybean (▲), 3) glyphosate POST plus inter-row cultivation in corn, and glyphosate POST in soybean (▼), 4) glyphosate POST in soybean rotated annually with a non-glyphosate herbicide program in corn (◆), 5) a non-glyphosate herbicide program in both corn and soybean (●), and 6) a PRE grass herbicide followed by glyphosate POST in both corn and soybean (□). Weed management treatments in NT included glyphosate applied as a burn-down.

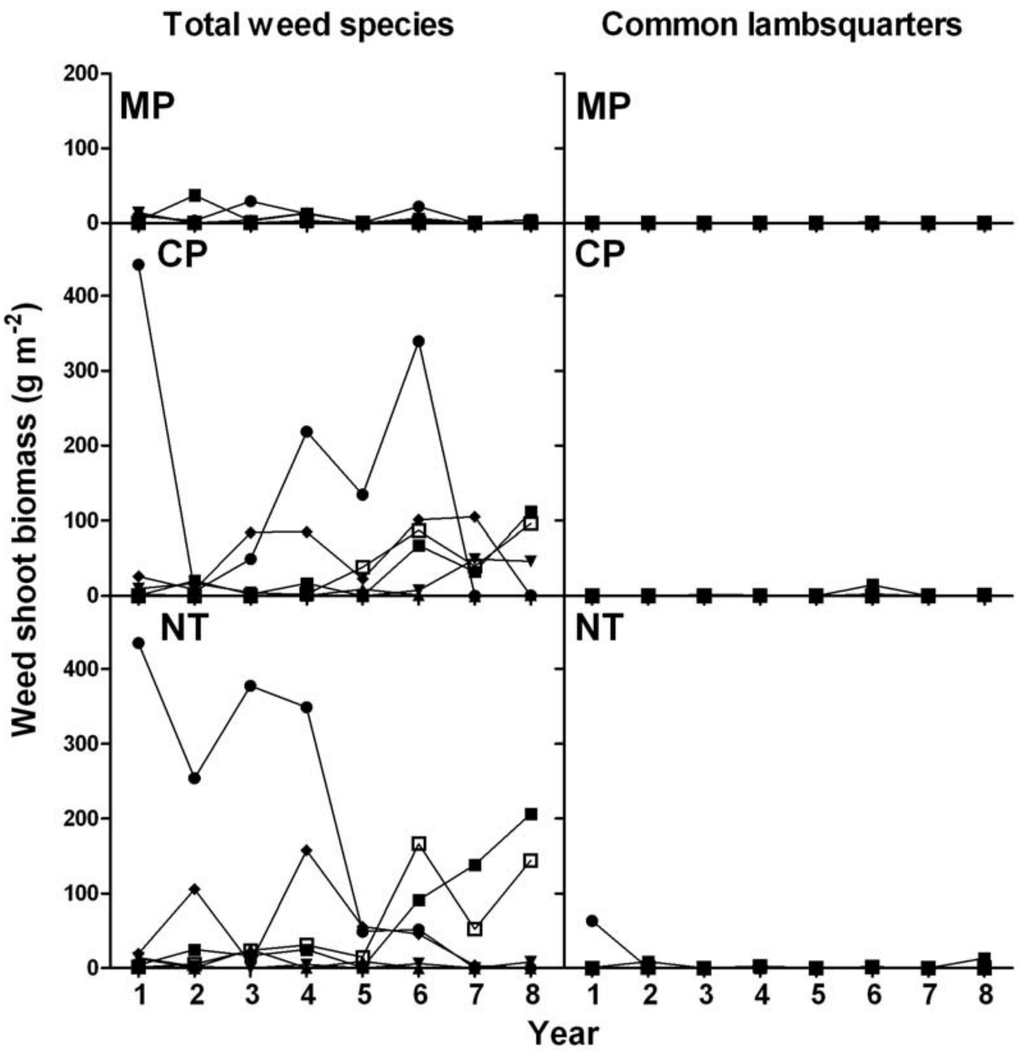

Figure 4. Late-season weed shoot biomass for total weed species and common lambsquarters from 1998-2005 as affected by moldboard plow (MP), chisel plow (CP), and no-tillage (NT) systems and weed management treatment in an annual corn-soybean rotation. Soybean was planted in 1998, 2000, 2002, and 2004; corn was planted in 1999, 2001, 2003, and 2005. Weed management treatments were 1) glyphosate POST in corn and soybean (■), 2) glyphosate POST and LPOST in corn and glyphosate POST in soybean (▲), 3) glyphosate POST plus inter-row cultivation in corn, and glyphosate POST in soybean (▼), 4) glyphosate POST in soybean rotated annually with a non-glyphosate herbicide program in corn (◆), 5) a non-glyphosate herbicide program in both corn and soybean (●), and 6) a PRE grass herbicide followed by glyphosate POST in both corn and soybean (□). Weed management treatments in NT included glyphosate applied as a burn-down.

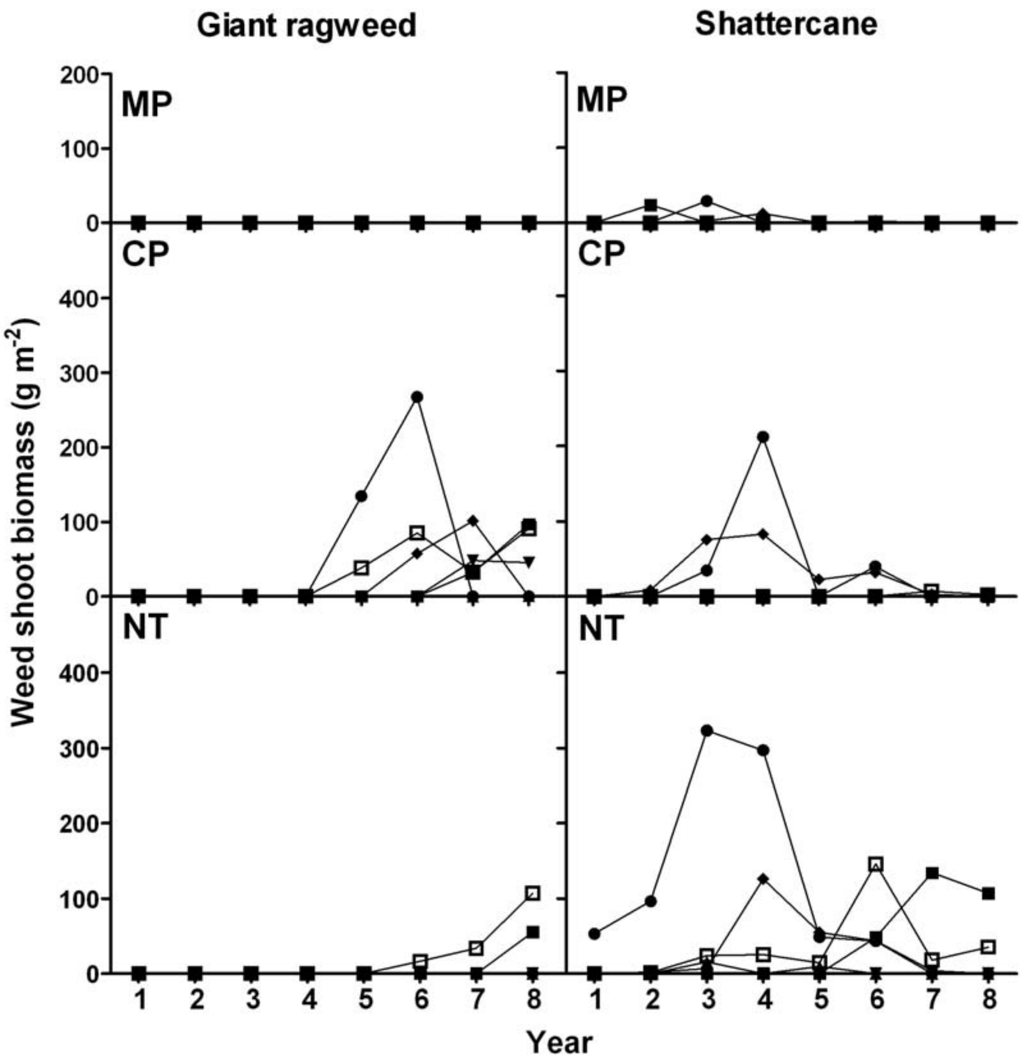

Figure 5. Late-season weed shoot biomass for giant ragweed and shattercane from 1998-2005 as affected by moldboard plow (MP), chisel plow (CP), and no-tillage (NT) systems and weed management treatment in an annual corn-soybean rotation. Soybean was planted in 1998, 2000, 2002, and 2004; corn was planted in 1999, 2001, 2003, and 2005. Weed management treatments were 1) glyphosate POST in corn and soybean (■), 2) glyphosate POST and LPOST in corn and glyphosate POST in soybean (▲), 3) glyphosate POST plus inter-row cultivation in corn, and glyphosate POST in soybean (▼), 4) glyphosate POST in soybean rotated annually with a non-glyphosate herbicide program in corn (◆), 5) a non-glyphosate herbicide program in both corn and soybean (●), and 6) a PRE grass herbicide followed by glyphosate POST in both corn and soybean (□). Weed management treatments in NT included glyphosate applied as a burn-down.

IS GIANT RAGWEED BECOMING RESISTANT TO GLYPHOSATE?

Mark M. Loux [1/]

One of the characteristics of Roundup Ready soybeans in the first few years following their introduction was the notable absence of weeds following postemergence glyphosate applications. This applied to relatively easy to control weeds as well as those that are not well controlled by other herbicides. Some growers continue to have excellent success at weed control in Roundup Ready soybeans. However, 10 years later, several weeds have become problematic in soybeans again, and we no longer assume that all Roundup Ready soybean fields will be free of weeds at the end of the season. Weeds that currently seem to be most problematic in Roundup Ready soybeans in the eastern Corn Belt include giant ragweed, lambsquarters, horseweed (marestail or Canada fleabane), and pokeweed. There can be any number of reasons why these weeds have become more prevalent, and more difficult to control. Within the United States, populations of horseweed, common ragweed, and Palmer amaranth have developed resistance to glyphosate over the past 5 years, and we believe populations of giant ragweed are developing resistance also.

Some problems are certainly due to the assumption by many growers that, even when grossly mismanaged, glyphosate will eventually control any population of weeds if applied often enough. This may have been true for several years after the adoption of Roundup Ready soybeans, but no longer seems to be the case in many fields. The ability of glyphosate to control a broad spectrum of weeds, even large weeds when necessary, does not change the need for the following components in weed management programs: (1) either a fall or spring treatment to control winter weeds, and early-emerging summer annuals; (2) an early postemergence glyphosate application when weeds are 4 to 8 inches tall; and (3) a second postemergence application as necessary to control late-emerging weeds or those not completely controlled with the first application. Producers who integrate glyphosate with other herbicides, as in the inclusion of 2,4-D ester and residual herbicides in fall or preplant treatments, may improve control of certain weeds, reduce the need for a second postemergence application, and reduce selection for glyphosate resistance. Deviation from this two to three application program can result in less effective weed control in general, and problems may be most acute with weeds such as giant ragweed, lambsquarters, and marestail.

Glyphosate Resistance Issues

Glyphosate-resistant marestail is widespread throughout Ohio and Indiana, especially in the southern areas. This problem has developed in continuous Roundup Ready soybean fields as well as fields where Roundup Ready soybeans have been rotated with corn. A primary cause of the problem appears to be use of exclusively glyphosate in

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the soybeans. The more frequent mid to late-season infestations of giant ragweed in the last several years could be an indication of the adaptation of weed populations to intensive use of glyphosate. The number of Roundup Ready soybean fields with giant ragweed control problems increased from 2005 to 2006, and we expect this to increase again into 2007. The most severe control problems appear to be occurring in continuous Roundup Ready soybean fields, with a history of reliance on exclusively glyphosate for weed control. Some of these fields were treated three to four times with glyphosate in 2006, and giant ragweed was still not well controlled.

Greenhouse research conducted over the past several years by OSU and Purdue University has resulted in the identification of populations of lambsquarters and giant ragweed that appear to have a low level of resistance to glyphosate. A number of these populations are from fields where control with glyphosate has been inadequate. We have the greatest concern about giant ragweed, which is generally more difficult to control in soybeans compared to lambsquarters, because glyphosate has been one of our most effective tools. In greenhouse and field dose response studies with these populations, we have observed giant ragweed surviving 3 lb ae/A of glyphosate, and also multiple applications of lower rates.

We conducted field studies at four sites in Ohio and Indiana in 2006 with giant ragweed populations that exhibited this type of response, with the goals of validating our greenhouse research findings and determining whether these populations could be controlled with glyphosate-based programs (Table 1). Plants survived multiple applications of glyphosate at all of these sites. We were not able to adequately control the giant ragweed where we used glyphosate exclusively, except at one site. We were able to obtain effective control at all sites where the weed management program consisted of all of the following: (1) a preplant burndown treatment that included glyphosate and 2,4-D ester; (2) an initial postemergence application of either glyphosate (1.5 lb ae/A) or Flexstar (1.3 pt/A) when plants were not more than about 6 to 12 inches tall; and (3) a second postemergence glyphosate application of 0.75 lb ae/A 3 weeks later. Where we included a residual herbicide in the preplant treatment (cloransulam plus flumioxazin, in this case), we obtained adequate control using the same sequence of treatments, but we were able to use 0.75 lb ae/A of glyphosate in the first postemergence application.

We were not able to adequately control giant ragweed with single postemergence glyphosate application, even where we used a preplant burndown and residual herbicide. In addition, although we observed adequate control with these programs, we almost always observed plants surviving and producing seed. This was our second year of research at one of these sites, and we made similar observations on control the previous year. Based on the results of these studies, we have concluded that giant ragweed populations with a low level of resistance to glyphosate have developed. These populations are not consistently controlled where glyphosate is the only herbicide used, which may explain some of the giant ragweed control failures evident in Ohio and Indiana in 2006.

Table 1. Results of 2006 field research conducted by OSU and Purdue University on control of giant ragweed in fields with a history of glyphosate performance problems (glyphosate-resistant giant ragweed). Data for resistant populations represent the average of four sites, as compared to control at one glyphosate-sensitive site. Glyphosate rates in ( ) are lb acid equivalent per acre. POST glyphosate was applied when most of the giant ragweed plants were 6 to 12 inches tall, except in plots where no burndown was applied, where plants were 15 to 25 inches tall. Burndown herbicides = glyphosate + 2,4-D ester. Residual herbicide = cloransulam plus flumioxazin.

	% control – at harvest	
	Resistant	Sensitive
No preplant burndown – POST only		
POST glyphosate (075)	37	73
POST glyphosate (0.75) + Late POST glyphosate (0.75)	74	85
Preplant burndown followed by POST		
POST glyphosate (0.75)	55	83
POST glyphosate (0.75) + Late POST glyphosate (0.75)	88	100
POST glyphosate (1.5)	61	75
POST glyphosate (1.5) + Late POST glyphosate (0.75)	96	100
POST Flexstar (1.3 pts/A) + Late POST glyphosate (0.75)	99	100
Preplant burndown + residual followed by POST		
POST glyphosate (0.75)	70	95
POST glyphosate (0.75) + Late POST glyphosate (0.75)	97	100
POST glyphosate (1.5)	71	90
POST glyphosate (1.5) + Late POST glyphosate (0.75)	97	100

Management Strategies – Soybeans

Giant ragweed has a number of characteristics that make it a "great" weed, and inherently difficult to control. Giant ragweed emerges from late March through early July in Ohio, and management programs need to address this long period of emergence. It is usually present at the time of planting, and should be controlled with an effective preplant burndown treatment. A combination of preemergence and postemergence herbicides should be used to control this weed from planting through late June. Several preemergence herbicides have activity on giant ragweed, and these should be used to reduce the populations that emerge after planting, and slow the growth of surviving plants. It is possible to obtain adequate control with single postemergence glyphosate application in fields without a history of control problems, but only where an effective preplant burndown and residual herbicides have been used. The populations and emergence pattern in many fields justify two postemergence applications. Giant ragweed grows rapidly and is extremely competitive with soybeans, and should be controlled when relatively small, which usually results in the need for a second postemergence application to control later-emerging plants.

While many growers rely on multiple applications of glyphosate to control giant ragweed, this has led to control failures in some fields, and the development of populations with a low level of glyphosate resistance. Based on recent research from Purdue University and The Ohio State University, it is still possible to control giant ragweed with glyphosate-based herbicide programs in fields where previous reliance on glyphosate alone has resulted in resistance and poor control. Growers experiencing problems with control should follow the guidelines shown below as closely as possible. Where control of giant ragweed has not been a problem, and the soybeans have been rotated with non-Roundup Ready corn, growers may choose not to use residual herbicides. We strongly suggest that no-till soybeans be treated with a preplant application of 2,4-D ester even where problems with control have not been experienced. Specific guidelines are as follows:

1. Start weedfree at planting using tillage or a preplant burndown herbicide treatment consisting of 2,4-D ester plus either glyphosate or paraquat.

2. In no-till, include an herbicide that provides residual control of giant ragweed in preplant burndown treatments. Where the field is tilled prior to planting, apply residual herbicide before soybeans emerge. The following preemergence herbicides provide some control of giant ragweed, so they can reduce the population and slow the growth of remaining plants: Authority First, Canopy, Synchrony, FirstRate, Scepter, Sonic, or Gangster. Note - these herbicides will not control ALS-resistant giant ragweed.

3. Growers with a history of giant ragweed control problems should apply one of the following POST treatments when giant ragweed plants are no more than 6 to 10 inches tall: glyphosate (1.5 lb ae/A); Flexstar (1.3 pints/A); Cobra/Phoenix (12.5 oz/A); or FirstRate (0.3 oz/A – only where population is not ALS resistant). Where Flexstar, Cobra, Phoenix, or FirstRate is applied, include a POST grass herbicide such as clethodim or Fusion. In fields where control has not been a problem, use a glyphosate rate of 0.75 lb ae/A on plants up to 6 inches tall, and 1.5 lb ae/A on larger plants.

4. In fields with a history of control problems, make a second POST application of glyphosate (0.75 lb ae/A) approximately 3 weeks after the first POST treatment. Proper timing of this application is essential to obtain control. Do not delay application until giant ragweed plants are evident above the soybean canopy, or control will be reduced. Where control has not been a problem in the past, scout fields 3 weeks after the first POST treatment. Make a second POST glyphosate application (0.75 lb ae/A) as necessary to control late-emerging plants or to complete control of plants that survive the first application.

Management Strategies – Corn

Giant ragweed should be effectively controlled throughout the crop rotation, and strategies in corn are overall similar to those in soybeans. In Ohio, too many growers attempt to control giant ragweed in corn with total preemergence herbicide programs. OSU research has shown that even the most effective preemergence corn herbicide programs, such as Lexar, Lumax, and mixtures of atrazine with Balance or Hornet, are unlikely to adequately control giant ragweed except in fields with very low populations. Where the risk of water contamination precludes use of atrazine, or allows only low rates, preemergence herbicide programs will be even less effective. Many postemergence broadleaf herbicides have activity on giant ragweed, although resistance to ALS inhibitors in some fields can limit the number of options. Effective management of giant ragweed in corn, which minimizes early-season interference and ensures control of late-emerging plants, results from a combination of preemergence and postemergence herbicides. Preemergence herbicide treatments used in this approach should provide enough control during the several weeks following planting, so that postemergence herbicides can be applied when corn is approximately 15 inches tall. This ensures control of late-emerging giant ragweed, which may not interfere with corn, but can still produce seed and interfere with harvest.

Resources for More Information

The recommendations presented here can also be found in the "Weed Control Guide for Ohio and Indiana", which is available on the OSU weed science website or from the OSU publications office (614-292-1607). Weed scientists at OSU and Purdue University have also collaborated on several fact sheets on the value of preemergence herbicides in Roundup Ready soybeans and control of lambsquarters and giant ragweed. Weed scientists across the Midwest have collaborated on a series of bulletins on glyphosate stewardship and resistance, and control of specific weeds that can be problematic in Roundup Ready systems. Free copies of these fact sheets and bulletins are available from extension weed scientists at OSU (Mark Loux, 614-292-9081, loux.1@osu.edu). They can also be downloaded from the following websites:

OSU weed science– http://agcrops.osu.edu/weeds
Purdue weed science – http://www.btny.purdue.edu/weedscience/
Glyphosate, Weeds and Crops group – http://www.glyphosateweedscrops.org

NEW WEED CONTROL OPTIONS FOR SWEET CORN

Joe Bollman, Chris Boerboom, Roger Becker, and Vince Fritz[1]

Callisto (mesotrione) and Impact (topramezone) are the two HPPD-inhibiting herbicides that are currently labeled for postemergence use on sweet corn. Laudis (tembotrione) is another HPPD-inhibiting herbicide that is currently under development by Bayer CropScience for postemergence use on sweet corn. Laudis may be available as soon as 2008 for commercial use. While Callisto is primarily for broadleaf weed control, Impact and Laudis are active on both broadleaf and grass weeds. Impact and Laudis would be the only other options for postemergence grass control other than Accent (nicosulfuron) and Poast (sethoxydim) on sethoxydim-resistant (SR) sweet corn hybrids. Accent has a risk of injuring sensitive fresh market and processing hybrids and only a limited number of SR sweet corn varieties are currently available. Previous research has shown hybrids can have differential tolerance to Callisto, however, little information has been provided about potential injury risks with Impact or Laudis.

Callisto is labeled at 3 oz/a for postemergence applications in sweet corn. Several practices to prevent or minimize sweet corn injury from Callisto are: 1) do not use the adjuvants urea ammonium nitrate (UAN) or ammonium sulfate (AMS); 2) do not apply Callisto postemergence to sweet corn that has been treated with Counter or Lorsban.; 3) do not tank mix Callisto with organophosphate or carbamate insecticides; and 4) do not apply foliar postemergence applications of organophosphate or carbamate insecticides 7 days prior to or 7 days after Callisto applications. Weeds controlled by Callisto are listed in Table 1. Rotational restrictions are listed in Table 2.

Table 1. Weed control ratings of selected postemergence sweet corn herbicides. †

		Callisto	Impact	Accent	Poast
Grass	Barnyardgrass	P	F/G	**G/E**	**E**
	Crabgrass	F/G	F/G	P	**E**
	Fall Panicum	P	F	**G**	**E**
	Foxtails	P	F/G	**G/E**	**E**
	Field sandbur	P	–	**G**	**E**
	Wild proso millet	P	F	**G/E**	**E**
	Woolly cupgrass	P	F	**G/E**	**G**
Broadleaf	Cocklebur	**G**	**G**	P	N
	Common ragweed	F/G	**G**	P	N
	Giant ragweed	**G**	**G**	P	N
	Eastern black nightshade	**E**	**G/E**	P	N
	Common lambsquarters	**E**	**E**	P	N
	Pigweeds	**E**	**E**	**G**	N
	Smartweeds	**E**	**G**	**G**	N
	Velvetleaf	**G/E**	**G/E**	F	N
Perennial	Canada thistle	P/F	F	P	N
	Hemp dogbane	P	–	P/F	N
	Nutsedge	F	–	P	N
	Quackgrass	P	–	**G/E**	F/G

† Control ratings: E=excellent; G=good; F=fair; P=poor; N=none; – = insufficient information

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Table 2. Planting intervals for selected rotational crops after applications of Callisto, Impact, Accent, or Poast.

Herbicide	Alfalfa	Barley	Snap beans	Oats	Peas	Potato	Soybean	Wheat
Callisto	10M	120D	18M	120D	18M	10M	10M	120D
Impact	9M	3M	18M	3M	9M	9M	9-18M†	3M
Accent	10M	8M	10M	8M	10M	10-18M‡	15D	4-8M§
Poast	0	0	0	0	0	0	0	0

† Wait 9M if using 0.5 oz/a rate.
‡ If the soil pH is 6.5 or greater do not plant for 18M.
§ 4M for spring wheat and 8M for winter wheat.

Impact is labeled at 0.75 oz/a unless rotating to soybean. Use 0.5 oz/a if rotating to soybean the following season. The use of methylated seed oil (MSO) and crop oil concentrate (COC) are both labeled adjuvants, but MSO is recommended if possible. A nitrogen fertilizer adjuvant is also recommended. Impact works synergistically with atrazine, so tank mixtures with 0.25 to 1.0 lb ai/a atrazine are recommended. Weeds controlled by Impact are listed in Table 1. Rotational restrictions are listed in Table 2.

Laudis is a new HPPD herbicide that is planned to be registered in 2008. Laudis is currently under development at a use rate of 3.0 oz/a. Final adjuvant requirements and rotational restrictions have not been released at this time.

Efficacy of HPPD-Inhibiting Herbicides in Sweet Corn

Field experiments were conducted at Arlington, WI and Waseca, MN in 2006 to compare herbicide efficacy of Callisto, Impact, and Laudis to several other postemergence programs for broadleaf control. The sweet corn hybrid Legacy was used at both locations. Table 3 lists the treatments used in the experiments.

Table 3. HPPD-inhibiting herbicides and selected broadleaf herbicide treatments evaluated for efficacy in sweet corn.

Herbicide	Timing	Rate	Atrazine	NIS	COC	28% UAN
Lumax	Pre	3 qt/a				
Dual II Magnum	Pre	1.66 pt/a				
fb† Laudis	Post	3 fl oz/a			1%	3 pt/a
fb Laudis	Post	3 fl oz/a	3 pt/a		1%	3 pt/a
fb Callisto	Post	3 fl oz/a		0.25%		
fb Callisto	Post	3 fl oz/a	3 pt/a	0.25%		
fb Impact	Post	0.5 fl oz/a			1%	3 pt/a
fb Impact	Post	0.5 fl oz/a	3 pt/a		1%	3 pt/a
fb Permit	Post	0.67 oz/a	3 pt/a	0.25%		
fb Aim	Post	0.5 oz/a	3 pt/a	0.25%		
fb Laddok	Post	2.33 pt/a				

† fb = followed by.

Postemergence treatments were applied when weeds reached 2 to 4 inches. Weed control ratings were evaluated at 14 and 35 days after treatment. Trials were harvested mechanically and fresh ear weights were recorded.

Efficacy Results

Impact and Laudis, with or without atrazine, provided better giant foxtail control than Callisto when applied after Dual II Magnum at both locations (Table 4). Common lambsquarters control was greater than 90% for all treatments at both locations. Atrazine synergized Impact at the Wisconsin site increasing common lambsquarters control from 91 to 100%. All treatments at Wisconsin controlled velvetleaf at 96% or greater. No statistical differences in velvetleaf control at Minnesota were observed even though the Permit + atrazine treatment only controlled 89% of the velvetleaf. Common ragweed control at Wisconsin was at least 95% for all treatments. Atrazine synergized Callisto at Minnesota increasing common ragweed control from 87 to 100%. Sweet corn yields did not differ among the herbicide treatments.

Table 4. Weed control and yield following postemergence applications of HPPD-inhibiting and other broadleaf herbicides. †

	GIFT		COLQ		VELE		CORW		Yield	
Treatment	WI	MN	WI	MN	WI	MN	WI	MN	WI	MN
	control (%)								tons/a	
Lumax pre	84	99	100	100	100	100	100	100	6.3	7.5
Dual II Magnum pre										
fb ‡ Laudis	89	96	98	100	96	100	98	97	6.0	7.3
fb Laudis + atrazine	97	99	100	100	100	100	100	100	6.1	7.1
fb Impact	98	97	91	98	98	96	95	97	6.6	6.5
fb Impact + atrazine	98	99	100	100	100	100	100	99	6.8	7.1
fb Callisto	82	87	100	100	100	100	96	87	6.4	7.1
fb Callisto + atrazine	82	89	100	100	100	100	100	100	6.7	6.6
fb Permit + atrazine	73	91	99	100	100	89	99	85	5.9	7.3
fb Aim + atrazine	81	81	100	100	100	100	100	87	7.0	6.9
fb Laddok S-12	81	94	99	100	100	100	100	99	7.1	6.6
Nontreated	-	-	-	-	-	-	-	-	3.0	1.9
LSD p=0.05	6	7	8	3	4	18	7	6	1.3	1.2

† GIFT = giant foxtail, COLQ = common lambsquarters, VELE = velvetleaf, CORW = common ragweed

‡ fb = followed by.

Sweet Corn Tolerance to HPPD-Inhibiting Herbicides

Field experiments were conducted at Arlington, WI and Waseca, MN in 2006 to test postemergence applications of Callisto, Impact, and Laudis on six sweet corn hybrids that have suspected low, medium, and high sensitivity based on previous experience with Callisto. The six hybrids tested were Cahill, Dynamo, GH 2042, GH 2547, GH 9597, and Merit. Three herbicide treatments were applied at labeled (1x) and twice labeled (2x) rates. The labeled rates for each herbicide are listed below:

1. Laudis at 3 fl oz/a + 1 pt/a atrazine + 1% COC + 1.5 qt/a 28% UAN
2. Callisto at 3 oz/a + 1 pt/a atrazine + 1% COC
3. Impact at 0.75 fl oz/a + 1 pt/a atrazine + 1% COC + 1.5 qt/a 28% UAN

A preemergence treatment was applied to the entire trial to prevent early season weed competition. The postemergence treatments were applied at the V3-V4 growth stage on June 29 at Arlington and June 26 at Waseca, MN. Crop stunting and chlorosis were evaluated at 7, 14, and 35 days after treatment (DAT). The experiments were harvested for green husk yields. The yields of the nontreated controls are not reported for Waseca because of partial competition from broadleaf weeds.

Tolerance Results

Stunting and chlorosis were greater at the 2x rates of these herbicide treatments. However, the results presented below are the average of the 1x and 2x rates. The hybrid Merit had more stunting and chlorosis than the other five hybrids in the HPPD- inhibiting herbicide tolerance trial (Table 5). This was expected because Merit is homozygous sensitive for the *nsf*1 gene, which encodes a P_{450} enzyme that metabolizes these HPPD-inhibiting herbicides. Laudis killed Merit whereas Callisto stunted Merit by at least 20% at each location. Stunting by Laudis of the other five hybrids was significantly less than the stunting of Merit. Laudis had less than 1% stunting at Arlington, WI and stunting was less than 10% among the five other hybrids at Waseca, MN. Other than with Merit, Callisto caused less stunting than either Laudis or Impact. Impact caused less than 10% stunting of any hybrid at each location.

Table 5. Hybrid injury from three HPPD-inhibiting herbicides when applied with atrazine at 7 days after treatment. Ratings are the mean of the 1x and 2x rates of each herbicide.

		Arlington, WI		Waseca, MN	
Treatment	Hybrid	Stunting	Chlorosis	Stunting	Chlorosis
		----------------------%	-----------------------		
Laudis + atrazine	Cahill	0	1	4	3
	Dynamo	0	1	7	2
	GH 2042	0	1	7	7
	GH 2547	0	1	5	4
	GH 9597	0	1	8	3
	Merit	95	3	94	80
Callisto + atrazine	Cahill	0	9	2	1
	Dynamo	1	25	4	8
	GH 2042	0	11	4	6
	GH 2547	0	2	2	0
	GH 9597	0	3	1	2
	Merit	22	62	23	40
Impact + atrazine	Cahill	0	1	5	4
	Dynamo	0	3	9	5
	GH 2042	0	3	5	3
	GH 2547	0	1	4	3
	GH 9597	0	1	4	3
	Merit	0	2	7	3

Merit had the greatest chlorosis with the Laudis and Callisto treatments. The discrepancies between locations for chlorosis with Laudis are meaningless because Merit was nearly dead at this rating date (Table 5). Callisto caused greater chlorosis of Merit than Impact. Dynamo had the most chlorosis with Callisto at both locations of the five remaining hybrids. Dynamo and GH 2042 at Arlington, WI were the only herbicide by hybrid combinations with greater than 10% chlorosis. GH 2547 and GH 9597 had less than 5% chlorosis for all three herbicides at both locations.

GH 2547 and GH 9597 yielded less when treated with the 2x rate of Laudis than with the 1x rate at Waseca, MN (Table 6). Callisto reduced the yield of Merit when comparing the 1x and 2x rates to the control at Arlington, WI, but hybrid yields were similar at Waseca after 1x and 2x rates of Callisto. Dynamo, GH 2042, and Merit had lower yields with 2x rates of Impact at Arlington, WI while GH 2547 and GH 9597 had lower yields at 2x Impact rates at Waseca, MN. Excluding Merit and averaging across the other five hybrids, Laudis and Impact reduced sweet corn yields with the 2x rate as compared with the 1x rate at Waseca, MN (Table 7). There were no differences in yield among the herbicides at Arlington, WI when averaging the yields of these five hybrids.

Table 6. Hybrid yield following treatment with three HPPD-inhibiting herbicides when applied with atrazine at 1x and 2x rates.

		Arlington, WI			Waseca, MN		
Treatment	Hybrid	Control	1x rate	2x rate	Control	1x rate	2x rate
		Tons/acre					
Laudis + atrazine	Cahill	4.7	5.2	5.1	- †	7.9	7.2
	Dynamo	7.9	8.4	8.8	-	11.9	11.2
	GH 2042	5.6	5.2	5.5	-	9.3	8.4
	GH 2547	6.5	6.6	6.5	-	11.5	10.3
	GH 9597	5.1	6.4	6.4	-	9.3	7.8
	Merit	6.3	0.1	0	-	0.5	0.1
Callisto + atrazine	Cahill	4.6	4.4	5.2	-	8.1	7.1
	Dynamo	6.5	6.4	6.5	-	9.8	9.4
	GH 2042	5.8	4.8	5.4	-	6.9	7.5
	GH 2547	6.3	6.6	5.9	-	11.0	10.5
	GH 9597	6.1	6.7	5.7	-	9.2	8.9
	Merit	5.7	4.4	4.1	-	8.7	8.0
Impact + atrazine	Cahill	5.4	5.5	5.2	-	7.3	7.1
	Dynamo	7.7	7.0	6.2	-	9.8	8.9
	GH 2042	6.2	6.7	5.1	-	8.8	8.4
	GH 2547	5.9	6.1	5.5	-	10.7	8.7
	GH 9597	6.0	6.5	6.4	-	9.0	7.0
	Merit	5.9	7.5	4.5	-	8.9	8.2
			$LSD_{0.05}$ = 1.4			$LSD_{0.05}$ = 1.0	

† The control plots were not harvested because partial weed competition reduced yields.

Table 7. Mean yield of Cahill, Dynamo, GH 2042, GH 2547, and GH 9597 following treatment with three HPPD-inhibiting herbicides when applied with atrazine at 1x and 2x rates.

	Arlington, WI			Waseca, MN		
Treatment	Control	1x rate	2x rate	Control	1x rate	2x rate
			Tons/acre			
Laudis + atrazine	5.9	6.4	6.5	- †	10.0	9.0
Callisto + atrazine	5.9	5.8	5.8	-	9.0	8.7
Impact + atrazine	6.2	6.4	5.7	-	9.1	8.0
		$LSD_{0.05}$ = 0.7			$LSD_{0.05}$ = 0.7	

† The control plots were not harvested because partial weed competition reduced yields.

HPPD-Inhibiting Herbicide Conclusions

Impact provides better giant foxtail control than Callisto. Impact provided excellent control of the broadleaf weeds evaluated when tank-mixed with atrazine. The sweet corn hybrids that were tested for tolerance to Impact displayed minimal visual injury. However, sweet corn yields were less when treated with the 2x rate than with the 1x rate at Waseca, MN. Additional research is warranted to validate the potential effect of Impact on sweet corn yield.

Laudis provided better giant foxtail control than Callisto. Laudis provided excellent giant foxtail control when tank-mixed with atrazine and good to excellent control of the broadleaf weeds evaluated even without atrazine. Laudis killed the hybrid Merit, which is homozygous sensitive for the *nsf*1 gene. Excluding Merit, the sweet corn hybrids that were tested for tolerance to Laudis displayed minor visual injury. However, sweet corn yields were less when treated with the 2x rate than with the 1x rate at Waseca, MN. Additional research is warranted to validate the potential effect of Laudis on sweet corn yield.

Callisto provided less giant foxtail control than Impact or Laudis. Callisto provided good to excellent control of the broadleaf weeds evaluated. A wide range of visual injury was observed for Callisto, but yields were only reduced with the highly sensitive hybrid Merit.

PROSPECTIVE HERBICIDES FOR VEGETABLE CROPS: RESEARCH UPDATE

Jed Colquhoun and Dan Heider [1]

Research was conducted in the 2006 growing season to evaluate potential herbicides in cabbage, table beets, carrots, and snap bean. The intent of this paper is to provide an update on these research projects. *However, keep in mind, the majority of the herbicide products mentioned are NOT labeled on these crops.* As always, check and read the label prior to any herbicide use. A summary of these projects is included below.

Cabbage. Research was conducted to evaluate experimental applications of Chateau (flumioxazin) applied 1, 3, and 7 days pre-transplant and 7 days post-transplant. Rates included 1.0 and 2.0 ounces of product per acre. Slight cabbage injury was observed when Chateau was applied at the higher rate 1 or 3 days prior to transplanting. Common lambsquarters, redroot pigweed, velvetleaf, and giant foxtail control were greatest when Chateau was applied 7 days after transplanting and least when the herbicide was applied 7 days prior to transplanting. Weed control was greater than 90% when Chateau was applied at either rate 1 or 3 days pre-transplant or 7 days post-transplant. Cabbage yield was greatest when Chateau was applied 7 days after transplanting.

Table beets. Twenty-three potential herbicide programs were evaluated. Crop injury was excessive where Define (flufenacet), Prowl H_2O (pendimethalin), or Everest (flucarbazone) were applied. Early post-emergence Betanex (desmedipham) applications also injured beets up to 23%. Injury was minimal where Dual Magnum (s-metolachlor) was applied pre-emergence. Yield of beets larger than 2 inches in diameter was greatest in programs that included Roneet (cycloate) plus Pyramin (pyrazon) pre-emergence or Dual Magnum plus Pyramin. Note: Outlook (dimethenamid) is no longer registered on table beet.

Carrots. Research was conducted to evaluate herbicides specifically for control of swamp dodder in carrot production. Swamp dodder is a parasitic weed that draws water and nutrients from the host plant. It is not a new pest in Wisconsin, but has recently spread to new production areas. Swamp dodder control was greatest where Matrix (rimsulfuron) or Everest were applied, however, injury from Matrix was substantial. Carrot injury was least where Prowl H_2O, Lorox (linuron), Goal (oxyfluorfen), or Define were applied. Carrot yield was greatest where Prowl H_2O or Everest were applied. Several of the evaluated herbicides injured carrots; however, this injury may be outweighed in some cases by the subsequent dodder control and reduced carrot parasitism that can severely reduce crop yield and quality.

Snap bean. Thirty potential herbicide programs were evaluated in 2006 primarily for crop safety and yield. Visual evaluations of crop injury were less than 10% in all treatments. Sandea (halosulfuron) applied to 1-trifoliate snap beans 18 days after planting slightly injured the crop, however, Sandea applied pre-emergence caused no visual injury. Post-emergence applications of Raptor (imazamox) + Basagran (bentazon) and non-ionic surfactant were compared with and without ammonium sulfate (AMS; 8.7 lb/100 gal). Dual II Magnum (s-metolachlor) was applied pre-emergence in these treatments. While crop injury was similar when Raptor + Basagran were applied both with and without AMS, crop yield tended to be lower when AMS was added.

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MANAGING INSECTICIDE RESISTANCE IN ONION THRIPS

Russell L. Groves[1/] and Scott A. Chapman[2/]

Management of onion thrips continues to be a high pest priority for Wisconsin onion growers. In 2006 the hot and dry conditions experienced in mid-summer led to increased populations that were very difficult to control in some areas. Furthermore, many of the earlier registered products for control of onion thrips are loosing control efficacy. Onion thrips insensitivity to λ -cyhalothrin (Warrior®) is suspected in Wisconsin similar to that which has been proposed in Ontario, Canada (Allen et al., 2005) and in New York populations using a thrips insecticide bioassay system (TIBS) (Shelton et al., 2003). Local insensitivity to Lannate® may also be occurring with increasing leaf damage following foliar applications and only 'fair' control of thrips populations. As a result, onion thrips management should be a top priority along with the potential for onion thrips to spread Iris yellow spot virus (IYSV) (Gent et al., 2004). An improved understanding of the ecology and management of onion thrips on a broad scale is essential to develop methods of control for this pest and to develop effective resistance management plans.

Onion growers in Wisconsin currently have a very limited range of insecticidal products available. Since the enactment of the Food Quality Protection Act (FQPA) in 1996, regulatory actions continue to threaten the long-term availability of the older, higher-risk compounds. FQPA is currently focused on the organophosphates and carbamates which effectively represent nearly half of the registered materials for onion thrips control. Furthermore, pending reviews may expand to include the synthetic pyrethroids as well. This will ultimately lead to a very narrow spectrum of available control options at a time when the chemical industry often foregoes seeking registrations of new materials on minor crops. Onion growers do, however, have some control over how rapidly insensitivity and resistance develops to the remaining arsenal of compounds and chemistries by developing well conceived, resistance management plans.

Recently registered for use in 2006, SpinTor® 2 SC is a new Naturalyte class of insecticide containing metabolic, fermentation products of the fungus, *Saccharopolyspora spinosa*, and appears to provide good thrips control as a population suppressive compound (Fig. 1). Product coverage and early season applications at thresholds were crucial for adequate control of onion thrips using this product. In 2006, New York, Michigan and Colorado were granted a crisis exemption for the use of Carzol® SP as a foliar insecticide treatment to manage onion thrips. In Oregon and Idaho, a Section 18 was granted for the same use. Unregistered, pending materials for thrips control also show some promise for control of onion thrips. Both abamectin (Agrimek® 0.15 EC) and spinetoram (Radiant® 2SC) performed remarkably well when compared to control efficacies of the two most currently used materials, λ-cyhalothrin and methomyl.

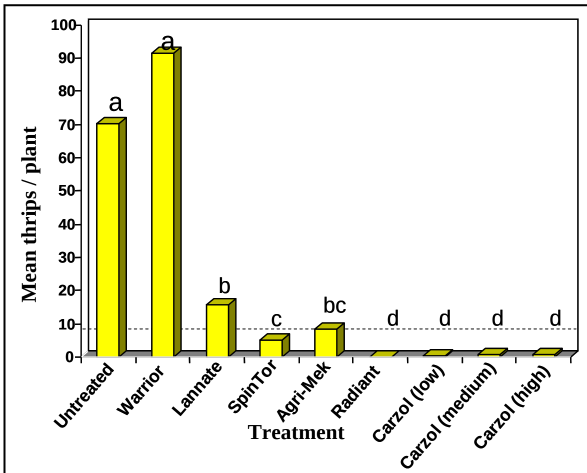

Figure 1. Season average onion thrips control using foliar-applied insecticides, Potter, NY, 2006 (B.A. Nault, Cornell University)

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Resistance management programs for onion thrips control are now under development in other onion producing regions of the US. In New York, the TIBS was recently implemented to survey thrips populations in commercial fields to the two most widely used classes of insecticides, λ-cyhalothrin and methomyl (Shelton et al., 2005). Assays performed in 2003 demonstrated significant variability in the spatial and temporal patterns of susceptibility to λ-cyhalothrin whereas field rates of methomyl still provided sufficient control. In 2005, a year in which onion thrips densities were much higher than in previous years, producers were unable to control populations of onion thrips in specific field locations and attributed this lack of control to developing resistance. Bioassays (TIBS) performed in 2005 did not, however, result in dissimilar levels of response to either λ-cyhalothrin or methomyl among test populations and resulted in surprisingly similar levels of control. The authors suggested that variation in thrips control may have been due, in part, to other factors including localized high populations, poor spray coverage, application intervals, and different onion varieties.

Exploration of novel management approaches is warranted in order to devise a more comprehensive management plan with an emphasis on insecticide resistance management. An initial approach is the use of cultural practices to reduce the attractiveness and likelihood that onion plants will be colonized by thrips. Ongoing research trials in Colorado have indicated that onion test plots with straw mulch(es) may reduce thrips colonization and total populations with observed reductions in thrips populations of up to 65%. Furthermore, mulches on onions have been shown to decrease IYSV incidence by up to 60%. Additional studies have also shown that onions produced on mulches have higher marketable size and weight compared to onions grown on bare soil, thus increasing the growers' net return. Intercropping of various plant species has also been investigated to compare reductions in colonization rates of onion thrips and overall reductions in yield (Trdan et al., 2005). Moreover, reflective mulches have been evaluated as an additional means of reducing the apparency of plants and extending the interval over which thrips colonize the susceptible crop, although this approach has been met with very little success. Another novel development of disease and insect control is the utilization of aqueous formulations of particle films. Particle film is based on kaolin and its coating serves as a physical barrier repelling arthropods and/or suppressing infestations by making the plant visually or tactually unrecognizable as a host. Ongoing research in New York reports that these materials hamper insect movement, feeding and other physical activities. Such technology has effectively suppressed plant diseases and several plant-feeding insect pests, without affecting plant growth and marketability.

Current guidelines for onion thrips on onions which was originally developed in Michigan is an action threshold of 3 thrips per green leaf. The effectiveness of this decision tool may have been useful for onion growers in Michigan at the time of its development, but may be inadequate for the conditions and currently registered materials in Wisconsin. Specifically, this guideline was developed at a time prior to the onset of any known insensitivity. Moreover, the relative effectiveness of a currently labeled insecticide must be considered when recommending a specific threshold. Conversely, some currently registered materials with apparent resistance, or lower toxicity, may require a lower action threshold to reduce populations below an economic threshold. Other compounds with greater efficacy may be applied at a higher, adjusted threshold and thus each insecticide may require a different threshold, but present guidelines do not consider this.

A comprehensive, insecticide resistance management approach for long-term control of onion thrips will undoubtedly be multi-tactic and should include, where possible, all available technologies to a) reduce the attractiveness of onion plants, b) delay the arrival of the dispersing populations infestation, c) correctly time pest control applications with appropriate equipment, and d) use effective remedial measures to lower population densities. To accomplish this, growers and pest control practitioners must be aware to avoid the consecutive use of insecticidal products with similar modes of action, or EPA numbered group, against onion thrips. Further, avoid using tank mixes of different insecticidal groups as this approach has been demonstrated to be effective only when there is no known resistance to either chemistry and if both materials have similar residual activity. Also, strict adherence to sampling plans and field scouting will improve the timing of required applications at appropriate thresholds. As is often the case in early season thrips colonization of fields, treat only the infested portions of fields where thresholds have been exceeded (spot spray), which is often adjacent to fallow field margins where thrips overwintering success is greatest. Achieving good spray coverage is also a critical component of an effective onion thrips resistance management plan. This is often achieved with higher spray volumes and the addition of non-ionic surfactants. It has also been well documented that natural mortality factors, including biological control, can greatly impact thrips populations. As such, the use of selective insecticide chemistries (e.g., SpinTor® 2 SC), which have less adverse effects on non-target organisms, should be used where possible. Finally, agricultural producers and pest managers need to remember that many factors can undermine insecticide efficacy and these factors may be independent of insecticide resistance. It is imperative to make an effort to understand the cause(s) of a perceived efficacy problem as a first step to resolving such an issue. It is very important to seek information from the product supplier, the crop consultant, and an appropriate extension specialist to determine why an issue arose and develop a plan to avoid any future problem. This area of pest management seems extremely important and relevant to the needs of the onion industry especially in light of the potential invasion of IYSV.

References

Allen, J.K.M., C.D. Scott-Dupree, J.H. Tolman, and C.R. Harris. 2005. Resistance of Thrips tabaci to pyrethroid and organophosphorus insecticides in Ontario, Canada. Pest Mgmt. Sci. 61:809-815.

Gent, D.H., H.R. Schwartz, and R. Khosla. 2004. Distribution and incidence of IYSV in Colorado and its relation to onion plant production and yield. Plant Dis. 88:446-452.

Shelton, A.M., B.A. Nault, J. Plate, and J.Z. Zhao. 2003. Regional and temporal variation in susceptibility to lambda-cyhalothrin in onion thrips in onion fields in New York. J. Econ. Entomol. 96:1843-1848.

Shelton, A.M., J.Z. Zhao, B.A. Nault, J. Plate, F.R. Musser, and E. Larentzaki. 2006. Patterns of insecticide resistance in onion thrips (Thysanoptera: Thripidae) in onion fields in New York. J. Econ. Entomol. 99:1798-1804.

Trdan, S., D. Znicdarcic, N. Valic, L. Rozman, and M. Vidrih. 2006. Intercropping against onion thrips, *Thrips tabaci* Lindeman (Thysanoptera : Thripidae) in onion production: on the suitability of orchard grass, lacy phacelia, and buckwheat as alternatives for white clover. J. Plant Dis. Prot. 113:24-30.

ALTERNATIVE SYSTEMS FOR PROCESSING VEGETABLES

Alvin J. Bussan[1]

Vegetable production occurs in many regions across Wisconsin, but no where is it more concentrated than on the irrigated sand soils of Central Wisconsin. The capacity for irrigation and the flexibility the sandy soils provide in terms of planting and harvest allow for optimal production of a number of different vegetable crops. However, these production systems are vulnerable to large environmental impacts because of the intensive crop management practices utilized for vegetable production and the nature of the sand soils. Many vegetable growers in the Central Sands and other regions of the state are interesting in improving the sustainability of their systems. Meeting the goal of enhanced sustainability will require development of systems with enhanced profitability for growers and reduced environmental impacts from the system.

Research on alternative production systems has been initiated to address goals of production systems with increased farmer profits and reduced environmental impacts. The primary focus of this research has been on improving the nitrogen use efficiency of the system. The first objective has been to remove more of the fertilizer nitrogen from the field in the form of the harvested crop. To meet this objective would require increasing the yield of the crop without increasing or decreasing the amount of fertilizer required to produce a crop with similar yield and quality. The second objective has been to retain more of the nitrogen not utilized by the crop in the field. To meet the second objective, requires practices that tie up nitrogen and keep it available for the following crop in the rotation.

A number of research trials have been initiated to address the goal of enhanced sustainability. These include annual cover crops, perennial cover cropping, intercropping, manures, use of varieties with improved nitrogen use efficiency, and utilization of organic nutrient management practices such as green and organic amendments. This paper will include brief introduction of perennial cover cropping under sweet corn. Much of this is preliminary research but represents opportunities available to begin rethinking annual vegetable crop production.

Perennial Cover Cropping

One of the challenges on the Central Sands is the loss of soluble nutrients, primarily nitrate, prior to crop harvest or before the establishment of a cover crop is possible. An approach that would minimize the potential for nitrogen leaching would be to establish cover crops that would have minimal interference on crop production, potentially supply nutrients to the vegetable crop, and still be standing after crop harvest. Use of kura clover as a perennial cover crops has been demonstrated in field corn rotations at several locations in Wisconsin (Albrecht, UW Agronomy). However, there may be an opportunity to develop similar rotations within vegetable rotations. Our primary focus to date has been on the utilization of perennial cover crops in Central Wisconsin. The availability of irrigation increases the chances of success with this practice as the threat of soil moisture loss is mitigated.

Our initial focus has been on evaluation of cover crop establishment within a snap bean – sweet corn – potato rotation. Our initial plan was to compare inter-seeding of sweet clover, red clover, white clover, hairy vetch, and alfalfa within snap bean during the first phase of the rotation. We wanted to establish the cover crop during the snap bean production year to eliminate

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the need for irrigation after snap bean harvest. Initial results have led to incredible stands of the respective cover crops, but limitations on herbicide options and competition from cover crops has reduced yield and quality of snap bean to unacceptable levels. Research will continue to determine feasibility of optimizing snap bean production while under-seeding with different perennial legumes.

Sweet corn was planted into each of the perennial cover crops after it had been sprayed with glyphosate at 1 lb/a and disked. Sweet corn yield with no cover crop was about 2 ton/a without nitrogen and over 8 ton/a with nitrogen. Sweet corn yield under the perennial cover crop ranged from 6.5 to just over 8 ton/a without nitrogen, whereas sweet corn yield with nitrogen fertilizer was similar to the no cover crop check (Table 1). These preliminary results indicate that perennial cover cropping was able to supply nearly all the nitrogen fertilizer demands of sweet corn and that optimized yields would have only required an additional 20 to 30 lb/a of nitrogen.

Table 1. Sweet corn yield response to perennial cover crop with and without nitrogen fertilizer applied at the recommended rate.

	Yield (ton/a)	
Cover crop	0 N	Rec N
No cover crop	1.82	8.36
Hairy vetch	6.87	8.88
Alfalfa	6.45	8.08
Red clover	7.31	8.81
Sweet/Yellow clover	8.09	8.57
Alsike clover	7.14	7.85
LSD	0.97	

In addition, the nitrogen benefit of the cover crop in sweet corn, several species survived sweet corn production and continued to grow after sweet corn harvest. This eliminates the need for establishment of fall cover crop following sweet corn harvest. In addition, the perennial clovers may provide nitrogen for the subsequent potato crop that will be planted in 2007. Several questions remain related to this system, especially the influence of perennial clover on root rot development in snap. Another consideration is the effect of reduced tillage on root rot in snap bean as well.

This provides a snap shot of systematic changes could be done to improve sustainability of vegetable crop production. Much work remains to optimize the production system, understand influence of practices on nutrient cycling, determine environmental effects, and document profitability.

USING BIOIPM TOOLS TO REDUCE CROP INPUTS FOR PROCESSING SNAP BEANS AND CARROTS

Walter R. Stevenson[1/], Peter Rogers[2/] , and Kim Lesniak[2/]

Wisconsin continues to be a leader in the production of vegetables grown for processing, ranking first in the production of snap beans and third in carrot production. During the summer of 2003, we initiated a multiyear IPM program on carrots and processing snap beans with funding from EPA, The American Farmland Trust and the Midwest Food Processors Association. Project cooperators included carrot growers, snap bean growers, a prominent vegetable processor and an IPM consultant who provides IPM services to clientele. This project, focusing on pest management activities used in the production of carrots and snap beans, demonstrated changes in approaches to management of plant pests, the chemistry and amount of pesticides used, the cultivars being planted and use of disease forecasting tools used by growers. The project also highlighted areas where extension activities can further improve the adoption of IPM technology. More specifically the project documented that carrot growers have shifted from planting mostly disease susceptible cultivars to planting a wide array of disease resistant cultivars that contributed to a 43% reduction in toxicity scores for their pest management programs. Carrot growers also greatly reduced their use of FQPA pesticides while maintaining pest control at economic levels. Snap bean growers also greatly increased their adoption of advanced IPM tools, decreased the pesticide active ingredients being applied for pest control and significantly reduced their use of FQPA pesticides. Information from this study is helpful in identifying specific tools which growers will most likely adopt and which will most likely be supported by food processors. Information from this project will prove useful in moving the processing industry forward in the adoption of advanced IPM tools.

Specifics of the Project

Prior to the 2003 growing season we developed plans for evaluating advanced IPM techniques for both carrot and snap bean producers. In concert with Del Monte personnel, an IPM consultant and growers, we laid plans for large field scale evaluations to compare standard production practices with practices using advanced IPM tools. The following tables (Table 1 and 2) summarize the key differences between standard production practices currently used by the processing crop growers and what we termed the "Wisconsin Next Step" program that included the use of advanced IPM tools. At the outset of the project we proposed to work with at least two progressive growers representing at least 25% of the Wisconsin carrot acreage and two progressive snap bean growers. Plots were maintained on grower properties with their active participation in these research and demonstration trials. This active partnership fostered adoption of many of the practices we were testing on an expanded acreage as growers saw firsthand that these practices were effective in improving pest management with fewer and safer inputs.

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Table 1. Field activity plan for evaluation of IPM practices on carrots.

IPM Practice Category	Current Wisconsin Program	Wisconsin "Next Step" Program
Cultivar	Heritage, Fontana or Danvers	Bolero, Enterprise, Sirocco, Carson
Insecticide Program primarily for management of aster yellows	Asana sprays at AYI of 50 Scout weekly Infectivity assay every 2 weeks	Asana sprays at AYI of 75-100 Scout weekly Infectivity assay every 2 weeks
Fungicide Program primarily for management of Alternaria leaf blight and Cercospora leaf blight	Scout weekly from emergence Sprays begin when plants reach about 6" in height – calendar approach Spray weekly with fungicide Spray program consists of chlorothalonil each spray	Scout weekly from emergence Sprays begin at 1% disease Use TomCast Program – spray interval at 20 DSV, compare with 15 DSV for Heritage Alternate chlorothalonil and strobilurin chemistry beginning with chlorothalonil
Herbicide Program for management of broadleaf and grass weeds	Scout weekly Carefully timed sprays to coincide with crop growth and weed pressure	Scout weekly. Carefully timed sprays to coincide with crop growth and weed pressure

Table 2. Field activity plan for evaluation of IPM practices on snap beans.

IPM Practice Category	Current Wisconsin Program	Wisconsin "Next Step" Program
Cultivar	Standard cultivar selected by processor susceptible to white mold.	Pest tolerant (white mold, root rot, bacterial leaf blight) cultivar selected by processor
Biocontrol Program	No biocontrol applied	Treat field with Contans biocontrol at 2 lb per acre preplant and incorporate
Fungicide Program	Scout weekly from emergence Treat with with thiophanate methyl at 4-5 days after 10% bloom as precaution	Scout weekly from emergence Treat only if widespread white mold incidence in area (thiophanate methyl), but only as last resort
Insecticide Program Seed – SCM control	Treat seed with Lorsban	Treat seed with Gaucho or Cruiser - will also control PLH, BLB and aphids)
Plants	Foliar treatment is primary control	Foliar treatment to supplement seed treatment only if needed
PLH, BLB	Dimethoate, Asana – 1/sweep	Capture – low rate – 1/sweep
Aphids	Dimethoate - at winged aphid flight based on trap catch	Capture – at winged aphid flight based on trap catch and monitoring of soybeans at flowering for aphid alates, use of weather models to predict aphid flights
Pod Stage - ECB	Capture, Orthene - 30 to 7 dbh (days before harvest) (2 - 3 applications)	Capture – 30 to 7 dbh (days before harvest) (2 applications)
Herbicide Program	Scout weekly. Carefully timed sprays with options of Dual, Treflan or Eptam to coincide with crop growth and weed pressure	Scout weekly. Carefully timed sprays of Dual, Treflan, Eptam and/or Sandia (0.5 oz/A) to coincide with crop growth and weed pressure (Sandia application based on field history of pigweed and waterhemp)

Table 2 (continued).

Monitoring insect pests on snap beans	Aphids - Plant counts weekly – alates SCM - % stand / injury – early season BLB/PLH – weekly sweeps; PLH thresholds = ½ insect per sweep up to 1st trifoliate and 1 insect per sweep after 1st trifoliate; /BLB thresholds to be determined ECB – black light trap catches; scout field edge areas	Aphids - Plant counts weekly – alates SCM - % stand / injury – early season BLB/PLH – weekly sweeps; PLH thresholds = ½ insect per sweep up to 1st trifoliate and 1 insect per sweep after 1st trifoliate; /BLB thresholds to be determined ECB – black light trap (BLT) catches; scout field edge areas, several BLT's in area

SCM = seedcorn maggot; BLB = bean leaf beetle; PLH = potato leafhopper; ECB = European corn borer

Throughout the funding period, multiple meetings were held with individual growers and educational meetings were held where the findings stemming from this project were presented. Handouts and publications were prepared and distributed as additional educational materials.

Questionnaires were developed for the Wisconsin carrot and snap bean industry, based on the successful PPP (preventative practice points) questionnaire used to determine changes in farming practices by the WI potato industry. Questions were modified to reflect differences in production practices between potatoes, carrots and snap beans. Points were assigned to each practice and weighted to reflect low, medium and high value practices as these related to IPM adoption. Sections of each questionnaire included questions related to field and farm information, field scouting, weed control, insect control, disease control and soil fertility. The questionnaires also included a section asking for detailed information on pesticide use (products, rates and timing). Questionnaires were completed by snap bean and carrot growers prior to the start of the 2003 field trials to establish baseline levels of IPM adoption and pesticide use and at the end of the 2005 cropping season to determine whether changes in adoption of IPM practices and pesticide usage had occurred. During the process, all grower records pertaining to pesticide inputs were evaluated using the toxicity module included in the RealToolbox (SureHarvest) Farm Management Information System.

Carrot Production

Information related to the use and adoption of IPM practices indicated a PPP score virtually unchanged from the 2001 sampling period (Average score of 598 in 2001 vs. 586 in 2005) (Figure 1). Only one grower reported a sizeable increase in the PPP score during this period, but the remaining five growers reported slight reductions in the PPP scores. Since these scores are far from the expected increase of at least 20% for the reporting period, we took a closer look at the questions that seemed to play a critical role in the final PPP scores. This scoring system helped to simplify the evaluation of pesticide toxicity associated with pest management programs in each year.

Question 1 – List the carrot cultivars grown on your farm.

Cultivar Susceptibility	2001	2005
Susceptible cultivars	1221 acres (**70**% of acreage)	70 acres (**9**% of acreage)
Moderate susceptible to resistant cultivars	517 acres (**30**% of acreage)	1767 acres (**91**% of acreage)

Question 2 – Did you use a disease forecasting or weather based model to indicate fungicide applications according to environmental variables?

Response	2001	2005
Yes	0	4 (57%)
No	0	3 (43%)
Respondents	9	7

Question 3 – Did you block carrot varieties according to disease resistance?

Response	2001	2005
Yes	7 (78%)	5 (71%)
No	2 (22%)	2 (29%)
Respondents	9	7

Question 4 – Did you adjust fungicide programs according to disease resistance of cultivars?

Response	2001	2005
Yes	5 (56%)	6 (86%)
No	4 (44%)	1 (14)
Respondents	9	7

It appears that there were important shifts in the carrot cultivars grown for processing in Wisconsin during the reporting period. The cultivars grown today are much more likely to contain moderate to high levels of resistance to foliar diseases (Response to Question 1). In addition, over half of the growers are now using the relatively new innovation of a disease forecasting program to schedule fungicide applications (Response to Question 2). While the majority of growers block their plantings according to the perceived disease resistance of the cultivars (Response to Question 3), there was an increase in the number of growers who adjust their fungicide spray programs according to cultivar disease resistance (Question 4). Weather also had an important role in minimizing changes in the PPP scores. Weather in 2001 was much more ideal for disease development than weather in 2004 and 2005. Collectively, answers to these questions provide a better explanation for similar 2001 and 2005 PPP scores. As growers adopt more disease resistant cultivars and rely on disease forecasting programs, it appears that they use fewer IPM inputs such as intensive field scouting for disease and less intensive spray programs. In combination with years less favorable for disease development (2004/05), the total PPP scores remained unchanged while individual components of the PPP scores changed dramatically.

Significant changes occurred in pesticide use on carrots (Figure 2). Four out of six growers reported lower insecticide and fungicide use and 5/6 growers reported less total pesticide a.i. use. Growers reported a reduction of 0.07 lb ai insecticide, 2.33 lb ai fungicide and a combined 2.4 lb ai fungicide plus insecticide. This amounts to a 36% reduction of pesticide ai between the reporting years.

We also noted significant reductions in the toxicity of pest management programs between the two reporting years (Figure 3). Toxicity scores associated with insecticide use declined by 39.5 points while fungicide toxicity scores declined by 254.8 points. An overall reduction of 294.4 toxicity points (43% reduction) was observed when evaluating changes in fungicide and insecticide from 2001 to 2005.

Figure 1. Changes in the adoption of IPM practices between 2001 and 2005.

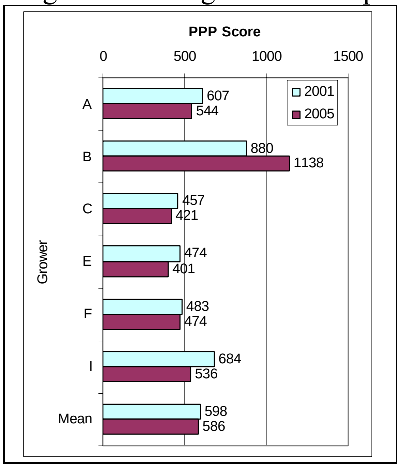


Figure 2. Changes in the use of insecticide and fungicide between 2001 and 2005.

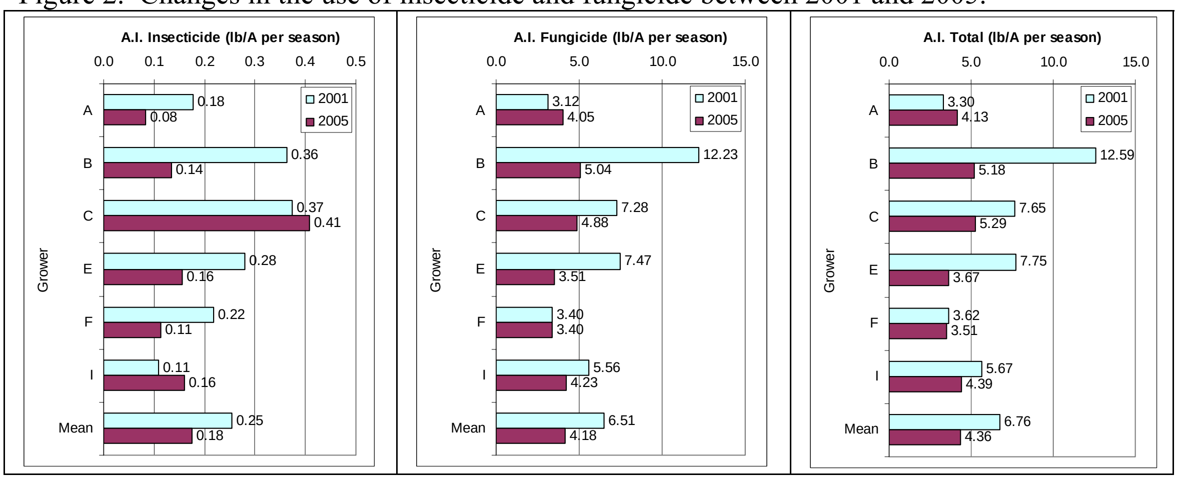
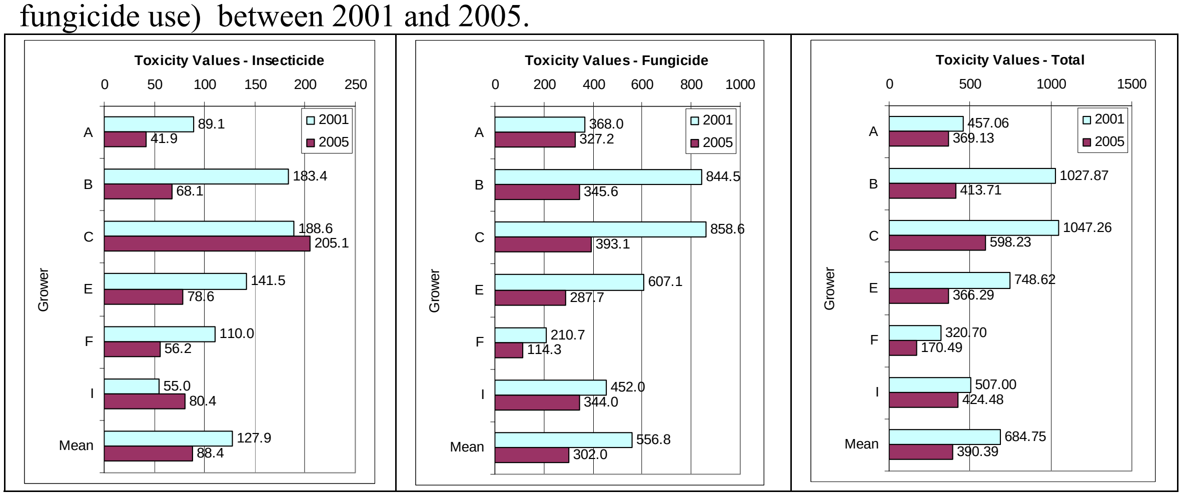


Figure 3. Changes in the toxicity of pest management programs (insecticide and fungicide use) between 2001 and 2005.



Snap Bean Production

Growers involved in our on-farm research and demonstration trials as part of this project appear to be altering their approaches to production activities. Table 3 compares the PPP score of a typical grower in 2003 with two growers in 2005. Provided with more information regarding black light insect catch data and local distribution of pest problems, growers appear to be taking a more active role in field scouting and pest management decisions. While the sample size is limited, the data provide a glimpse into how changes can occur at the local level for growers willing and interested in taking a more active role in the management of their crop. The PPP questionnaire provides information relative to how we could help growers improve their PPP scores even further.

Table 3. Summation of preventative practice points (PPP) for two typical snap bean growers in Wisconsin, comparing 2003 vs. 2005 production years.

Section	Grower A 2003	Grower B 2005	Grower C 2005
I: Specific Field Info	6 points	11 points	14 points
II: Field Scouting	30	309	450
III: Weed Control	8	22	20
IV: Insect Control	0	20	22
V: Disease Control	6	28	22
VI: Soil Fertility	4	4	4
TOTAL PPP Scores:	54	394	532

We were not able to calculate the toxicity factors for the pesticides used in snap bean production since much different chemistries are used on potatoes and carrots vs. snap beans. However we were able to evaluate the pesticides commonly used by the snap bean producers in 2003 vs.2005 and to calculate changes in the chemistries used and the amount of active ingredients applied (Table 4, 5 and 6). We observed a significant reduction in the amount of pesticide ai being applied in 2005 compared with 2003 and a change in the products used.

Table 4. Pesticide used in snap bean production on typical Wisconsin acreage in 2003.

Chemical	Formulation/acre	Formulation ai	Total lb ai applied
Eptam 7E	0.375 gal	7 lb/gal	2.625 lb ai
Dual II Magnum	1 pt	7.64 lb/gal	0.955
Capture 2EC	4.0 oz	2 lb/gal	0.062
Capture 2EC	6.4 fl oz	2 lb/gal	0.1
Benlate	1.5 lb	50%	0.75
			4.492

Table 5. Pesticide used in snap bean production on typical Wisconsin acreage (Grower B) in 2005.

Chemical	Formulation/acre	Formulation ai	Total lb ai applied
Roundup	1 gal	0.502 lb/gal	0.502 lb ai
Sandea	0.08 oz	0.75 lb/gal	0.06
Assure II	6 oz	0.88 lb/gal	0.041
Discipline 2EC	3 oz	2 lb/gal	0.046
Contans (Biological)	2 lb	5.3%	1.06
			1.66

Table 6. Pesticide used in snap bean production on typical WI acreage (Grower C) in 2005.

CHEMICAL	RATE	AI	LBS AI/ACRE
Contans	2 lbs	5.30%	1.06
Sandea	0.5 oz	75%	0.00225
Topsin M 4.5F	2.4 pt	45%	0.135
Discipline 2EC	2.5 fl oz	2 lb/gal	0.04
Dual II Magnum	1.3 pt	7.64 lb/gal	1.24
Sniper	2.5 fl oz	50%	0.0097
Poast	0.8 pt	18%	0.018
			2.504

Prior to the initiation of the project we anticipated that the adoption of advanced IPM methods would lead to sizeable reductions in several pesticides. Specifics of the observed reductions are shown below.

Carrots

Table 7 identifies significant reductions in the use of esfenvalerate (Asana replaced by Baythroid) (32.33% reduction in ai use), chlorothalonil (Bravo, Echo and Equus replaced by reduced risk materials Quadris, Cabrio and Endura) (55.92% reduction) and benomyl (Benlate no longer produced, registered on carrot or used by the carrot industry) (100% reduction).

Table 7. Change in use of pesticides by the Wisconsin carrot industry from 2001 to 2005.

Pesticides Applied – 6 Growers		LB AI Applied			
Chemical Name	Brand Name	2001	2005	Change	% Reduction
esfenvalerate	Asana	1.52	1.03	0.49	32.33
cyfluthrin	Baythroid	0	0.03	0.03	--
chlorothalonil	Bravo, Echo, Equus	30.97	20.90	10.07	32.51
benomyl	Benlate	0.50	0.00	0.50	100.00
fixed copper	Kocide, Champ	7.65	3.37	4.28	55.92
azoxystrobin, pyraclostrobin	Quadris, Cabrio	0.00	0.13	0.13	--
other - boscalid	Endura	0.00	0.59	0.59	--

As new safer materials are used in conjunction with improved IPM tools such as rapid identification of aster yellows phytoplasma using real time PCR, cultivars with resistance to aster yellows phytoplasma and leaf blight, biological controls and safer pesticide delivery technology, we expect to see additional reductions in pesticide use.

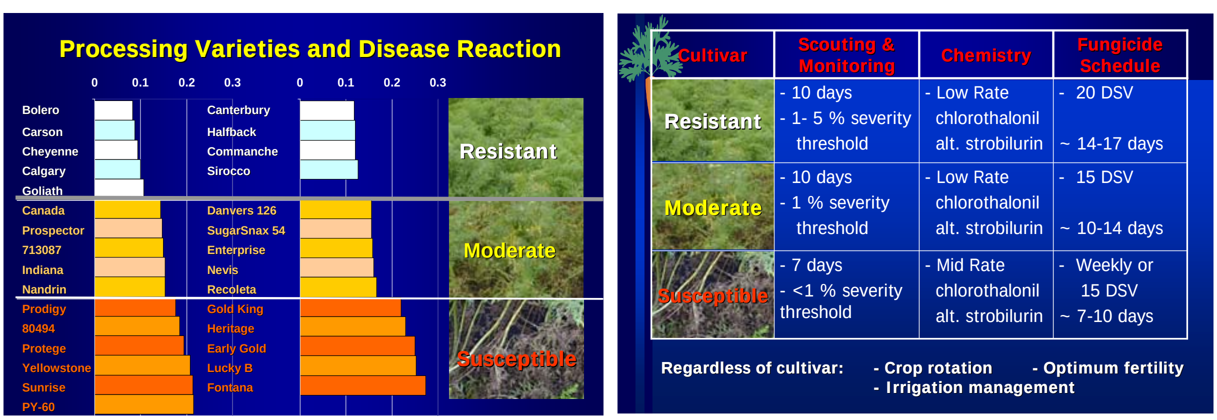
Snap Beans

Tables 4 to 6 identify reductions in the total pesticide ai used in the production of snap beans in Wisconsin. Some pesticides such as Eptam, Dual II Magnum and Benlate were eliminated from use by the reporting grower in 2005. Roundup and Sandea are used as herbicide substitutes for effective weed control. Benlate is no longer available for use in Wisconsin and while Topsin M could have been substituted for Benlate use, the reporting grower chose to use a biological control (Contans) to manage white mold. Several years of field research under a wide range of environmental conditions have convinced this grower to use Contans as a way to reduce pathogen survival of this soilborne pathogen. We have observed that application of Contans provides a level of white mold control equivalent in most years to a single fungicide spray at flowering. This same grower has now treated over 1,500 acres of a soybean/potato/snap bean rotation with Contans as a means to enhance white mold control on his entire farm. He remains encouraged by the performance of this product and serves as a "de facto" spokesman for use of this product. Within the foreseeable future, we expect to see snap bean acreage planted to snap bean cultivars with enhanced resistance to white mold. Host resistance combined with biological control of soilborne inoculum could very well make fungicide treatment of snap beans a method of the past.

Use of Project Information

Information related to this 2-year project was presented to multiple meetings attended by growers and processors since 2003. During this period there were a total of 17 presentations to state, regional, national and international audiences. In addition we published 17 articles in conference proceedings and on-line or printed publications. Examples of useful IPM information provided to carrot growers is exhibited in Figure 4.

Figure 4. Examples of carrot IPM information provided to the Wisconsin carrot industry.



THE WISCONSIN POTATO AND VEGETABLE STORAGE RESEARCH FACILITY

Charles J. Kostichka [1/]

July 26, 2006 marked a significant event in Wisconsin potato industry history. On that day, more than 400 people gathered at the Hancock Agricultural Research Station to talk about partnerships, cooperation, and the quest for knowledge, and to dedicate a shining example of all three— the Wisconsin Potato and Vegetable Storage Research Facility. The cutting of that red ribbon stretched across the west entrance to the Facility was the culmination of more than 20 years of discussions and 5 years of planning.

From the outside, it is impossible to guess what is contained inside. The sleek, shiny white exterior gives no indication of the inner workings. When passing through the entrance, the first thing most visitors note is the sheer size. The distance from floor to peak is some 30 feet. Brett Favre would have to give his all to toss the pigskin from end-to-end. The central work area is 40 feet wide. On either side are the Facility's heart and soul — bins and lockers, nine of each. The bins simulate typical, if there is such a thing, bulk storage. The lockers store small containers of potatoes and vegetables — crates, boxes, bags and buckets — under environmental conditions similar to bulk storage. When filled to capacity, some 2 million pounds of produce call the Facility home. Each bin and locker has its own air exchange, humidification and refrigeration systems. Although adjacent, each is sealed and separated from the others. Each is controlled independently by cutting-edge computer technology. There are no switches to flip and no dials to turn, only two brightly colored screens with images of buttons that one merely has to touch with a fingertip to make things happen. Each and every bin can be monitored and controlled from a laptop computer any place in the world where connection to the Internet is possible.

It was an exciting day in mid-September when the first plastic crates of tubers from research plots on the Hancock Station were wheeled into the Facility. It was even more exciting a couple of weeks later when that first truckload arrived from a local grower and those freshly lifted Russet Norkotahs made their way along the conveyors through the custom bin piler and gently rolled onto the floor of Bin 8. It was exciting not because rolling potatoes have any particular allure, but rather because that very first tuber represented commitment. The Wisconsin Potato and Vegetable Storage Research Facility was conceived by the growers, designed by the growers, and built by the growers of Wisconsin. It represents commitment from growers to their profession. It represents the trust of an industry in its university. On October 1, 2006 the potato and vegetable growers of Wisconsin turned the keys to this magnificent achievement over to their partners at the University of Wisconsin. Work is underway.

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HOW DO YOU MANAGE A CORN CROP AFTER STRESS?

Joe Lauer [1]

To understand how to manage a corn crop after stress, you must first understand how the corn plant develops and how genetics and environment influence yield. Corn growth and development occurs during a growing season with predictable stages. The plant is the ultimate integrator of the environment in which it grows. The environment has much more impact than we have with management, but we need to provide basic inputs at the right time in order to increase our chances for successful yields.

Grain yield in corn is comprised of the components: ears per unit area, kernel number per ear consisting of kernel rows and kernels per row, and kernel weight. Each of these yield components is determined at different stages in the lifecycle of the plant. Yield components develop by initial cell division near the growing point and formation of numerous primordial tissues that eventually become ears or kernels. Often the number of these early structures is greater than what the plant is later capable of supporting. The plant "adjusts" yield components according to environmental and management stresses that take place during the growing season.

The plant has the "potential" to produce more ears and kernels than what is "actually" harvested. For example, the corn plant typically produces 6 to 10 ear shoots, but only one ear (at most two) actually develops. In some years, hybrids may produce 20 rows of kernels on an ear, but most of the time only 12 to 16 rows of kernels develop on the hybrids used in Wisconsin. If you were to examine the ear shoot at the V18 stage (just prior to tasseling) using a microscope, you could count 50 to 60 kernel ovules in a row. Multiplying the number of kernel ovules by the number of kernel rows indicates that 600 to 1200 kernels could potentially grow on an ear. Usually only 300 to 600 kernels develop on the ears of Wisconsin hybrids. Likewise, test weight (an indirect measure of kernel weight) is affected by environmental stresses.

The tasseling, silking, and pollination stages of corn development are extremely critical because the yield components of ear and kernel number can no longer be increased by the plant and the potential size of the kernel is being determined. Table 1 describes when yield components are at their greatest “potential” and when under normal conditions are “actually” determined and are not further affected under typical conditions. For example, the potential number of ears per unit area is largely determined by number of seeds planted, how many germinate, and eventually emerge. Attrition of plants through disease, unfurling underground, insects, mammal and bird damage, chemical damage, mechanical damage, and lodging all will decrease the actual number of ears that can be produced. The plant often can compensate for early losses by producing a second or third ear, but the capacity to compensate ear number is largely lost by R1 and from then on no new ears can be formed.

Likewise, kernel number is at its greatest potential slightly before R1, the actual number of kernels formed is determined by pollination of the kernel ovule. The yield component of kernel number is actually set by pollination and fertilization of the kernel ovule. If the ovule is not pollinated, the kernel cannot continue development and eventually dies. No new kernels form after the pollination phase is past.

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The only yield component remaining with some flexibility is kernel weight. For the first 7 to 10 days after pollination of an individual kernel, cell division occurs in the endosperm. The potential number of cells that can accumulate starch is determined. At black layer formation (R6) no more material can be transported into the kernel and yield is determined.

Table 1. Corn growth and development stages when yield components are at maximum potential and actually determined (105 day hybrid).

Stage	GDU required to reach growth stage	Yield components: Potential	Yield components: Actual
VE (Emergence)	**125**	**Ears/area**	**-----**
V6 (six leaf collars)	**470**	**Kernel rows/ear**	**"Factory"**
V12	**815**	**-----**	**Kernel rows/ear**
V18	**1160**	**Kernels/row**	**-----**
R1 (Silking)	**1250**	**Kernel weight**	**Kernel number Ears/area**
R6 (Black layer)	**2350**	**-----**	**Kernel weight**

Identifying corn growth stages is necessary for post-emergence application of pesticides or growth regulators, to monitor the progress of seasonal development, and to determine the effect on yield of a hail storm, insect feeding, disease, drought or early frost. The objective of this paper is to describe management options for corn from cool wet soils, flooding, hail, lodging, drought, and frost stresses. The last section describes management options when pollination is poor.

Stress from cool, wet soils

Saturated soils, cool temperatures, wet weather are all prescriptions for delaying corn emergence and seedling development. Seeds and germinated seedlings will not sustain any measurable growth or development until soils have warmed above 50°F.

Of particular concern is the development of seedling blight diseases, as the cool conditions predispose the plant to root infection. Slower growth and development of the root system does not allow the plant to produce more root mass quickly enough to overcome bacterial damage, as a normal growing plant would.

The disease that will quickly take advantage of the stressed corn seedling is Pythium. Pythium is the most common cause for seed rots and seedling damping off in corn and thrives in saturated soils, and in soils between 45° and 53°F the corn plant's ability to defend itself and outgrow the infection is severely limited. A corn crop, during a period of cool, wet soil conditions, can suffer stand loss. This stand loss can be made worse when the crop is under some other stress, like frost injury.

Once the soils become saturated, corn seedlings suffer from lack of oxygen. Oxygen is a necessary element that all plants need in order to grow and develop. If roots are deprived of oxygen, the transport of nutrients and water ceases, and root formation comes to a standstill. This condition can only be solved by drier weather, or adequate drainage.

Flooding Stress

The extent to which flooding injures corn is determined by several factors including: plant stage of development when flooding occurs, duration of flooding, and air-soil temperatures.

Prior to V6 (6 visible leaf collars) the growing point is near or below the soil surface. Corn can survive only 2 to 4 days under flooded conditions. The oxygen supply in the soil is depleted after about 48 hours in a flooded soil. Without oxygen, the plant cannot perform critical life sustaining functions; e.g. nutrient and water uptake is impaired, root growth is inhibited, etc. If temperatures are warm during flooding (greater than 77 degrees F) plants may not survive 24-hours. Cooler temperatures prolong survival.

Once the growing point is above the water level, the chances of survival improve greatly. Even if flooding doesn't kill plants outright, it may have a long-term negative impact on crop performance. Excess moisture during the early vegetative stages retards root development. As a result, plants may be subject to greater injury during a dry summer because root systems are not sufficiently developed to access available subsoil water. Flooding and ponding can also result in losses of nitrogen through denitrification and leaching.

If flooding in corn is less than 48 hours, crop injury should be limited. To confirm plant survival, check the color of the growing point. It should be white to cream colored, while a darkening and/or softening usually precedes plant death. Also look for new leaf growth 3 to 5 days after water drains from the field.

Disease problems that may become greater risks due to flooding and cool temperatures are corn smut and crazy top. There is limited hybrid resistance to these diseases and predicting damage is difficult until later in the growing season.

Hail Stress

Those who advise growers faced with the likelihood of hail damage should prepare by consulting the National Corn Handbook NCH-1 "Assessing Hail Damage to Corn". This publication does a good job of describing factors to consider, and has charts used by the National Crop Insurance Association for assessing yield loss due to 1) stand reduction through tenth-leaf stage only, and 2) defoliation.

Hail affects yield primarily by reducing stands and defoliating the plant. Defoliation causes most yield loses. **Knowing how to recognize hail damage and assess probable loss is important for decision making.** The effect of hail damage on corn yield is well documented in agronomic literature. Hail adjusters use standard tables to calculate compensation for yield loss associated with hail. Four assessments are made on corn when hail occurs after silking (Vorst, 1990) including:

1. Determining yield loss due to stand reduction,
2. Determining yield loss due to defoliation,
3. Determining direct ear damage, and
4. Bruising and stalk damage.

Because it is difficult to distinguish living from dead tissue immediately after a storm, the assessment should be delayed 7 to 10 days. By that time regrowth of living plants will have begun and discolored dead tissue will be apparent.

Determining yield loss due to **stand reduction** is made by comparing yield potential of the field at its original population with yield potential at its now-reduced population. Yield loss after silking is adjusted directly by determining the percentage of killed plants. Likewise **ear damage losses** are adjusted directly by determining the percentage of damaged kernels on ears.

In corn, most yield reduction due to hail damage is a result of **leaf loss**. To determine yield loss due to defoliation, both the growth stage of the field and the percent leaf area removed from the plant must be determined. Significant yield damage due to defoliation occurs immediately after silking and decreases as the plant matures (Table 2).

Table 2. Estimated percent corn yield loss due to defoliation occurring at various stages of growth.

	Percent leaf area destroyed				
	20	**40**	**60**	**80**	**100**
Tassel	**7**	**21**	**42**	**68**	**100**
Silked	**7**	**20**	**39**	**65**	**97**
Blister	**5**	**16**	**30**	**50**	**73**
Milk	**3**	**12**	**24**	**41**	**59**
Dough	**2**	**8**	**17**	**29**	**41**
Dent	**0**	**4**	**10**	**17**	**23**
Black layer	**0**	**0**	**0**	**0**	**0**

derived from National Crop Insurance Service Bulletin

Damage due to **bruising** is determined at harvest by counting the number of lodged plants. Bruising may allow an avenue of infection for stalk rots and molds that cause mycotoxin problems. Weather conditions during the remainder of the season affect disease severity.

As the season progresses past the V-10 stage of development, hail injury and losses could become more significant. Some comments on concerns not covered by NCH-1:

1. **After** the tenth leaf stage, yield and stand reductions are on about a one-to-one ratio (eg. 80% stand = 80% potential) and are in addition to losses shown in the defoliation chart.
2. Plants with bruised, but not severed stalks or ears will usually produce a near normal, harvestable ear.
3. Growers should monitor stalk rot of severely defoliated plants which have a good-sized ear. Photosynthate will be mobilized towards the ear rather than the stalk. This could weaken the stalk and encourage stalk rot development. These fields may need to be harvested early to avoid standability problems.
4. Nitrate levels in corn may become elevated. Animal performance could be reduced. Growers with complete defoliation and high soil nitrogen levels (due to fertilizer, manure, or legume plowdown) should test nitrate levels and probably ensile the corn before feeding.
5. Late season leaf loss will allow more light to penetrate to the soil and late-season weed growth may flourish.

Secondly, an economic estimate should be made of the options (ie. corn grain, high-moisture corn, silage, snaplage, etc.) available in the grower's situation. Estimates of changes in yield and quality due to plant part loss should be taken into account. For corn grain yield, information from crop insurance hail adjusters tables would be a good source for making estimates. Little economic information on hail damage is available on other harvesting options such as silage, high-moisture corn, or snaplage. One approach would be to use yield and quality changes observed under normal development and conditions and adjust downward.

Hail during kernel grain-fill can be very detrimental to grain yield. Depending on the stage of development and the amount of leaf loss, grain yield can be reduced from 0 to 41 percent after the soft-dough stage of development. Any losses due to ear dropping would increase this yield loss estimate .

The types of options available to farmers varies from farm-to-farm and field-to-field. On a farm basis, the decision hinges on availability of other corn handling systems involving drying capacity, silage storage facilities, high moisture corn handling equipment, snaplage equipment, etc. Using these later systems means that the harvested corn product will probably have to be fed on-farm to livestock.

On a field basis, things to consider are mold development, moisture levels for ensiling, and effects on maturation rate, yield and quality. If ears are damaged, easier entry of mold causing organisms into the ear can take place. If it is wet for the duration of the season, mold problems will probably increase. Drier weather may not promote growth of mold producing organisms. Safer storage of corn predisposed to mold causing organisms can be achieved by drying grain to 15.5% moisture, ensiling at the proper moisture for the silo type, or treating high moisture corn with propionic or acetic acid.

Hailed corn will usually achieve physiological maturity earlier, but take longer to dry-down than non-hailed corn. Yield and test weight will likely decrease when stressed by hail.

If ensiling, hail damaged corn should be stored separately from other silage already put up. Hail damaged corn may have lower quality, and by storing separately, the farmer will have the option of mixing poor and good silages to obtain a satisfactory ration, or feeding the damaged silage to animals that do not have high quality forage requirements. An estimate of silage yield and quality should be obtained to compare with the grain yield estimate.

Lodging Stress

The time from silking to maturity is the time kernels are filled. Sugars are needed to simultaneously support the developing kernels and maintain stalk strength. Anything that restricts production or movement of sugars or competes with the stalk or kernels will decrease yield and increase death of root and stalk cells. Rotting organisms more easily enter the stalk reducing stalk strength. Numerous factors restrict or compete for sugars during grain fill including high grain yield, cloudy weather, drought stress, high temperatures, hail, early frost, leaf diseases, and European corn borer. The effect of lodging on various plant physiological processes such as energy required for altering stalk growth, nutrient uptake, water uptake, and light penetration and how these processes influence subsequent yield is not well studied.

The most sensitive stage for lodging to occur is during late vegetative growth stages when the stalk is at full height and brace roots have not yet formed. In a Wisconsin study, lodging occurring at V10 caused little damage, while lodging events that occurred near silking caused 15 to 30 percent yield loss in hand harvested plots (Carter and Hudelson, 1988). The upper regions of the plants straightened to vertical within 2 days following lodging. Lodging during vegetative growth stages did not affect plant development, as silk dates were identical for all treatments and lodging did not influence harvest grain moisture. Later lodging events lowered ear height more than 24 inches due to pronounced lower-stalk curvature.

No research has documented yield loss damage from specific lodging events after silking. Defoliation (Afuakwa and Crookston, 1984) effects on yield may provide some insight (Tables 3 and 3). Much will depend upon the ability of the plant to recover to an upright stature.

Table 3. Grain yield loss after plants killed or defoliated.

Corn Development Stage	Plants Killed	Plants Defoliated
	percent yield loss	
R4 (Soft dough)	55	35
R5 (Dent)	40	25
R5.5 (50% kernel milk)	12	5
R6 (Black layer)	0	0

derived from Afuakwa and Crookston, 1984

Guidelines for Managing Fields after Late-Season Hail and Lodging Events

The types of options available to farmers vary from farm-to-farm and field-to-field. On a farm basis, the decision hinges on availability of other corn handling systems involving drying capacity, silage storage facilities, high moisture corn handling equipment, snaplage equipment, etc. On a field basis, things to consider are plant recovery, mold development, moisture levels for ensiling, effects on maturation rate, and yield and quality. Safer storage of corn predisposed to mold causing organisms can be achieved by drying grain to 15.5% moisture, ensiling at the proper moisture for the storage structure, or treating high moisture corn with propionic or acetic acid.

Silage: Consider chopping a hailed or lodged field for silage, especially if grain prices are low. If ensiling, damaged corn should be stored separately from other silage already put up. Damaged corn may have lower quality, and by storing separately, there is an option of mixing poor and good silages to obtain a satisfactory ration, or feeding the damaged silage to animals that do not have high quality forage requirements. Rotary cutter heads for silage chopping may not be useable in lodged corn.

Grain: The amount of stalk straightening decreases when lodging occurs at VT or later. Harvest speed will likely need to be reduced, especially for lodging occurring later. Test weight will likely be reduced.

Weather has a strong influence on harvesting. It not only influences harvest timing, but also rate of stalk degradation and whether plants will be able to stand until you get to them. Temperature, rain, snow and wind all play key roles in the amount of lodging. Assessing the severity of lodging in fields will help in scheduling grain harvest later. Watch closely fields that were severely lodged and adjust timing of harvest if required.

Drought Stress

To begin talking about water influences on corn growth and development and yield we must begin with the concept of evapotranspiration. **Evapotranspiration** is both the water lost from the soil surface through **evaporation** and the water used by a plant during **transpiration**. Soil evaporation is the major loss of water from the soil during early stages of growth. As corn leaf area increases, transpiration gradually becomes the major pathway through which water moves from the soil through the plant to the atmosphere.

Yield is reduced when evapotranspiration demand exceeds water supply from the soil at any time during the corn life cycle. Nutrient availability, uptake, and transport are impaired without sufficient water. Plants weakened by stress are also more susceptible to disease and insect damage. Corn responds to water stress by leaf rolling. Highly stressed plants will begin leaf rolling early in the day.

Evapotranspiration demand of corn varies during its life cycle (Table 4). Evapotranspiration peaks around canopy closure. Estimates of peak evapotranspiration in corn range between 0.20 and 0.39 inches per day. Corn yield is most sensitive to water stress during flowering and pollination, followed by grainfilling, and finally vegetative growth stages.

Vegetative development

Water stress during vegetative development reduces stem and leaf cell expansion resulting in reduced plant height and less leaf area. Leaf number is generally not affected by water stress. Corn roots can grow between 5 and 8 feet deep, and soil can hold 1.5 to 2.5 inches of available soil water per foot of soil, depending upon soil texture. Ear size may be smaller. Kernel number (rows) is reduced. Early drought stress does not usually affect yield in Wisconsin through the V10-V12 stages. Beyond these stages water stress begins to have an increasing effect on corn yield.

Pollination

Water stress around flowering and pollination delays silking, reduces silk elongation, and inhibits embryo development after pollination. Moisture stress during this time reduces corn grain yield 3-8% for each day of stress (Table 4). Moisture or heat stress interferes with synchronization between pollen shed and silk emergence. Drought stress may delay silk emergence until pollen shed is nearly or completely finished. During periods of high temperatures, low relative humidity, and inadequate soil moisture level, exposed silks may desiccate and become non-receptive to pollen germination.

Table 4. Estimated corn evapotranspiration and yield loss per stress day during various stages of growth.

Growth stage	Evapotranspiration	Percent yield loss per day of stress (min-ave-max)
	inches per day	%
Seedling to 4 leaf	0.06	---
4 leaf to 8 leaf	0.10	---
8 leaf to 12 leaf	0.18	---
12 leaf to 16 leaf	0.21	2.1 - 3.0 - 3.7
16 leaf to tasseling	0.33	2.5 - 3.2 - 4.0
Pollination (R1)	0.33	3.0 - 6.8 - 8.0
Blister (R2)	0.33	3.0 - 4.2 - 6.0
Milk (R3)	0.26	3.0 - 4.2 - 5.8
Dough (R4)	0.26	3.0 - 4.0 - 5.0
Dent (R5)	0.26	2.5 - 3.0 - 4.0
Maturity (R6)	0.23	0.0

derived from Rhoads and Bennett (1990) and Shaw (1988)

To assess the success or failure of pollination, two methods are commonly used: counting attached silks and counting developing ovules. Each potential kernel on the ear has a silk attached to it. Once a pollen grain "lands" on an individual silk, it quickly germinates and produces a pollen tube that grows the length of the silk to fertilize the ovule in 12 to 28 hours. Within 1 to 3 days after a silk is pollinated and if fertilization of the ovule is successful, the silk will detach from the developing kernel. Unfertilized ovules will still have attached silks. By carefully unwrapping the husk leaves from an ear and then gently shaking the ear, the silks from the fertilized ovules will readily drop off. Developing ovules (kernels) appear as watery blisters (the "blister" stage of kernel development) about 10 to 14 days after fertilization of the ovules. The proportion of fertilized ovules (future kernels) on an ear indicates the progress and success of pollination.

Silk elongation begins near the butt of the ear and progresses up toward the tip. The tip silks are typically the last to emerge from the husk leaves. If ears are unusually long (many kernels per row), the final silks from the tip of the ear may emerge after all the pollen has been shed. Another cause of incomplete kernel set is abortion of fertilized ovules. Aborted kernels are distinguished from unfertilized ovules in that aborted kernels had actually begun development. Aborted kernels will be shrunken and mostly white.

Kernel development (grain-filling)

Water stress during grain-filling increases leaf dying, shortens the grain-filling period, increases lodging and lowers kernel weight. Water stress during grain-filling reduces yield 2.5 to 5.8% with each day of stress (Table 4). Kernels are most susceptible to abortion during the first 2 weeks following pollination, particularly kernels near the tip of the ear. Tip kernels are generally last to be fertilized, less vigorous than the rest, and are most susceptible to abortion. Once kernels have reached the dough stage of development, further yield losses will occur mainly from reductions in kernel dry weight accumulation.

Severe drought stress that continues into the early stages of kernel development (blister and milk stages) can easily abort developing kernels. Severe stress during dough and dent stages of grain fill decreases grain yield primarily due to decreased kernel weights and is often caused by premature black layer formation in the kernels. Once grain has reached physiological maturity, stress will have no further physiological effect on final yield (Table 1). Stalk and ear rots, however, can continue to develop after corn has reached physiological maturity and indirectly reduce grain yield through plant lodging. Stalk rots are seen more often when ears have high kernel numbers and have been predisposed to stress, especially drought stress.

Premature Plant Death

Premature death of leaves results in yield losses because the photosynthetic 'factory' output is greatly reduced. The plant may remobilize stored carbohydrates from the leaves or stalk tissue to the developing ears, but yield potential will still be lost. Death of all plant tissue prevents any further remobilization of stored carbohydrates to the developing ear. Whole plant death that occurs before normal black layer formation will cause premature black layer development, resulting in incomplete grain fill and lightweight, chaffy grain. Grain moisture will be greater than 35%, requiring substantial field drydown before harvest.

Management Decisions Will Depend Upon Success of Corn Pollination

After July, the key plant indicator to observe and base future management decisions upon is the success of pollination. Each ovule (potential kernel) has a silk attached to it. When a pollen grain falls on a silk, it germinates, produces a pollen tube that grows the length of the silk which fertilizes the ovule in 12 to 28 hours. If fertilization of the ovule is successful, within 1 to 3 days the silk will detach from the developing kernel. Silks will remain attached to unfertilized ovules and be receptive to pollen up to 7 days after emergence. Silks eventually turn brown and dry up after pollination is over.

Two techniques are commonly used to assess pollination success or failure. The most rapid technique to determine pollination success is the “shake test.” Carefully unwrap the ear husk leaves and then gently shake the ear. The silks from fertilized ovules will drop off. The proportion (%) of silks dropping off the ear indicates the proportion of future kernels on an ear. Randomly sample several ears in a field to estimate the success of pollination.

The second technique is to wait until 10 days after fertilization of the ovules. The developing ovules (kernels) will appear as watery blisters (the "blister" R2 stage of kernel development).

Growers questioning when to chop their corn for silage should wait until:

1. You are sure pollination and fertilization of kernels will not or did not occur and that whole-plant moisture is between 55-70%, so that fermentation can occur without seepage or spoilage losses.
2. If pollination and fertilization of kernels did occur, do not chop until you are sure that there is no further potential to increase grain dry matter and whole plant moisture is in the 55-70% range.

A few cautions and suggestions:

- Be sure to test whole-plant moisture of chopped corn to assure yourself that acceptable fermentation will occur. Use a microwave, an electronic forage tester, or the "grab-test" method for your determination.
- Follow precautions regarding dangers of nitrate toxicity to livestock (especially with green-chopping) and silo-gasses to humans when dealing with drought-stressed corn.
- Keep in mind that "normal" guidelines for determining when to harvest corn for silage will be useful for many, if not most, corn fields. These include using the kernel milkline, and beginning to harvest after the dent stage, when the milkline has moved towards the kernel tip.
- Growers need to carefully monitor, inspect and dissect plants in their own fields as to plant survival potential, kernel stages, and plant moisture contents in determining when to begin silage harvest. Fields and corn hybrids within fields vary greatly in stress condition and maturity.
- In order to estimate pre-harvest silage yields, the National Corn Handbook publication "Utilizing Drought-Damaged Corn" describes methods based on either corn grain yields or plant height (if little or no grain yield is expected).

Grain yield method for estimating silage yield: For moisture-stressed corn, about 1 ton of silage per acre can be obtained for each 5 bushels of grain per acre. For example, if you expect a grain yield of 50 bushels per acre, you will get about 10 tons/acre of 30% dry matter silage (3 tons/acre dry matter yield). For corn yielding more than 100 bushels per acre, about 1 ton of silage per acre can be expected for each 6 to 7 bushels of grain per acre. For example, corn yielding 125 bushels of grain per acre, corn silage yields will be 18 to 20 tons per acre at 30% dry matter (5 to 6 tons per acre dry matter yield). See also Table 2 in A1178 "Corn silage for the dairy ration."

Plant height method for estimating silage yield: If little or no grain is expected, a rough estimate of yield can be made assuming that 1 ton of 30% dry matter silage can be obtained for each foot of plant height (excluding the tassel). For example, corn at 3 to 4 feet will produce about 3 to 4 tons per acre of silage at 30% dry matter (about 1 ton per acre of dry matter).

Frost Stress

Farmers selecting corn hybrids for silage should first consider planting the latest relative maturity of corn that will reach harvest maturity by frost. Higher yields are produced with hybrids that mature slightly later than those adapted for grain production – perhaps 5 to 10 relative maturity units later. These hybrids will result in the highest yield of high quality forage.

When planting is delayed beyond May 20, earlier maturity hybrids should be planted to reach harvest maturity by frost. However there comes a point (about June 1 in northern Wisconsin and June 20 in southern Wisconsin) where planting is delayed to the extent that even shorter maturity hybrids will not reach harvest maturity by frost. At this point it is preferable to plant later maturity hybrids so they reach pollination at frost, and then allow drying after frost to get the hybrid to low enough moisture content for ensiling.

The recommendation to switch back to later maturity hybrids for late planted corn silage is made because corn has two peaks in forage quality: one at pollination and one at harvest maturity. The early peak in forage quality at pollination is high in quality but too wet for ensiling unless frost can dry the corn down. For late planted corn, aiming for a hybrid that will be at pollination at frost becomes a better choice than planting a short season hybrid that will not reach harvest maturity.

Typically in a normal year, corn should be "silking at the end of July and denting on Labor Day." After corn silks, it normally takes about 55 to 60 days for it to mature. Right now heading into Labor Day, we are seeing many fields which are between the silking and milk stages of development. These fields will require 700-1200 growing degree units in order to mature and another 150 units to be at a harvestable moisture (Table 5).

Table 5. Required growing degree units between corn development stages and maturity (black layer).

Corn	**Relative maturity zone *(days)***		
development	**85-90**	**95-105**	**110-120**
stage	**Growing degree units**		
R1 (silking)	**1000**	**1100**	**1200**
R2 (blister)	**800**	**880**	**960**
R3.5 (late milk / early dough)	**600**	**660**	**720**
R4.5 (late dough / early dent)	**400**	**440**	**480**
R5 (dent)	**200**	**220**	**240**
R6 Maturity (black layer)	**0**	**0**	**0**
Harvest (kernel moisture at 25%)	**150**	**150**	**150**

derived from Carter, 1991

Normally during September, growing degree units in Wisconsin accumulate at the rate of 12 to 19 units per day for a total accumulation of 400 to 450 units (Table 6). Likelihood of a 32 ° F freeze by September 20 is 3 years out of 5 in northern, and 1 year out of 5 in southern Wisconsin.

Table 6. Corn growing degree unit accumulation in Wisconsin.

	North			**South**		
Month	**Daily**	**Monthly**	**Total**	**Daily**	**Monthly**	**Total**
	Growing degree units					
May	**8-11**	**300**	**300**	**10-13**	**350**	**350**
June	**11-17**	**400**	**700**	**13-20**	**500**	**850**
July	**17-20**	**575**	**1275**	**20-23**	**650**	**1500**
August	**20-17**	**575**	**1850**	**23-19**	**650**	**2150**
September	**17-12**	**400**	**2250**	**19-13**	**450**	**2600**
October	**12-8**	**300**	**2550**	**13-10**	**350**	**2950**

derived from Mitchell and Larsen, 1981

Use tables 5 and 6 to determine the likelihood that a field will mature. For example, if on September 1, your field is at R3.5 (late milk / early dough) and you are in a 95-105 relative maturity zone, it will take about 660 growing degree units to mature the crop before it is killed by a frost. Since corn is usually killed in 3 out of 5 years by September 20 the field in all likelihood will accumulate about 300 to 380 growing degree units and be at the early dent to dent stage of development when it is killed by a frost.

For fields that only had light frost damage, it is too early to harvest. Growing conditions may improve during September allowing the crop to mature and produce reasonable grain and silage yields.

Corn is killed when temperatures are near 32 F for a few hours, and when temperatures are near 28 F for a few minutes. A damaging frost can occur when temperatures are slightly above 32 F and conditions are optimum for rapid heat loss from the leaves to the atmosphere, i.e. clear skies, low humidity, no wind. At temperatures between 32 to 40 F, damage may be quite variable and strongly influenced by small variations in slope or terrain that affect air drainage and thermal radiation, creating small frost pockets. Field edges, low lying areas, and the top leaves on the plant are at greatest risk. Greener corn has more frost resistance than yellowing corn.

Symptoms of frost damage will start to show up about 1 to 2 days after a frost. Frost symptoms are water soaked leaves that eventually turn brown. Because it is difficult to distinguish living from dead tissue immediately after a frost event, the assessment should be delayed 5 to 7 days.

Yield Impact

Yield losses are negligible if frost occurs when grain moisture is below 35 percent. Yield loss is directly proportional to the stage of maturity and the amount of leaf tissue killed. Those who will be advising growers about the likelihood of frost damage and its impact on yield should get ready by consulting the National Corn Handbook NCH-1 "Assessing Hail Damage to Corn" (Vorst, 1990). This publication has charts used by the National Crop Insurance Association for assessing yield loss due to defoliation. **Knowing how to recognize frost damage and assess probable loss is important for decision making.** An abbreviated version of the loss chart is shown in Table 7. For example, corn that was defoliated 20% at the milk stage would have 3% yield loss.

Table 7. Estimated percent corn yield loss due to defoliation occurring at various stages of growth.

	Percent leaf area destroyed				
Stage of growth	**20**	**40**	**60**	**80**	**100**
			Yield loss (%)		
Tassel	**7**	**21**	**42**	**68**	**100**
Silked	**7**	**20**	**39**	**65**	**97**
Blister	**5**	**16**	**30**	**50**	**73**
Milk	**3**	**12**	**24**	**41**	**59**
Dough	**2**	**8**	**17**	**29**	**41**
Dent	**0**	**4**	**10**	**17**	**23**
Black layer	**0**	**0**	**0**	**0**	**0**

derived from Vorst (1990)

The stem on a corn plant is a temporary storage organ for material that eventually moves into the kernels (Afuakwa and Crookston, 1984). Grain yield will continue to increase about 7 to 20% after a light frost that only kills the leaves as long as the stem is not killed (Table 3).

Moisture drydown

Corn silage should be harvested at the appropriate moisture content for the type of silo in which it will be stored. If corn is frosted prior to 50% kernel milk, the moisture content of corn may be too high to be properly ensiled. However, during the drydown period, dry matter yield will decrease due to leaf loss, plant lodging and ear droppage. Thus, a trade-off exists between moisture and yield.

For corn silage frosted prior to the dent stage, the moisture content will be too high for successful ensiling. The silage crop should be allowed to dry in the field for several days and moisture content should be monitored. For corn frosted during the dent stage, harvest should begin quickly to prevent yield loss as damaged leaves are shed or break off the plant.

Since mold can occur on the ears before the desired moisture level is reached, harvest may have to begin immediately. To help control problems with excess moisture, wet silage can be mixed either with ground grain, straw, or chopped hay to reduce the overall moisture of the stored silage, The rule of thumb is about 30 pounds of dry material per ton of silage will be needed to reduce silage moisture one percentage unit.

Grain quality impact

Late season frost damage can affect grain quality and is directly proportional to the stage of maturity and leaf tissue killed. Severe impacts on grain quality can occur at mid-dough, while moderate impacts are seen at the dent stage. By the time the kernel has reached half milk line only minor impacts will occur to grain quality. Differences among hybrids, overall plant vigor at the time of frost and subsequent temperatures will all affect final grain quality.

Other considerations

Growers should monitor stalk rot of severely defoliated plants which have a good-sized ear. Photosynthate will be mobilized towards the ear rather than the stalk. This could weaken the stalk and encourage stalk rot development. These fields may need to be harvested early to avoid standability problems.

If frosted corn is ensiled at the proper moisture content and other steps are followed to provide good quality silage, nitrate testing should not be necessary. However, it is prudent to follow precautions regarding dangers of nitrate toxicity to livestock (especially with grazing and green-chopping) and silo-gasses to humans when dealing with drought-stressed corn.

Management Guidelines for Handling Cornfields With Poor Pollination

Typical management options and uses are available for corn that has successfully pollinated. If pollination is unsuccessful, we are usually trying to make the best of a bad situation. If **pollination is good**, harvest in a normal fashion for either grain or forage use. If **pollination is poor** yet some kernels are developing, the plant can gain dry matter and farmers should wait with harvest. In Wisconsin, many farmers have the option of harvesting poorly pollinated fields for silage use. If there is **no pollination**, then the best quality forage will be as found as close to flowering as possible. Quality decreases after flowering. The challenge is to make sure that no potential pollination occurs and that the forage moisture is correct for the storage structure.

Drought-stressed corn can be grazed or used for forage, either as green chop or silage. Because of the potential for nitrate toxicity, grazing or green chopping should be done only when emergency feed is needed. The decision to chop corn for silage should be made when:

1. You are sure pollination and fertilization of kernels will not or did not occur and that whole-plant moisture is in the proper range for the storage structure so that fermentation can occur without seepage or spoilage losses. If there is no grain now, florets on the ear were either not pollinated or have not started to grow due to moisture stress, and the plant will continue to be barren. If the plant is dead, harvest should occur when whole plant moisture is appropriate for preservation and storage.
2. If pollination and fertilization of kernels did occur but it was poor, do not chop until you are sure that there is no further potential to increase grain dry matter and whole plant moisture is in the proper range for the storage structure. These kernels may grow some now, if the plant is not dead and in those fields receiving rain. If kernels are growing dry matter is accumulating and yield and quality of the forage is improving.

Green, barren stalks will contain 75-90% water. If weather remains hot and dry, moisture content drops, but if rain occurs before plants lose green color, plants can remain green until frost. Drought stressed corn has increased sugar content, higher crude protein, higher crude fiber and more digestible fiber than normal corn silage. Drought generally reduces yield and grain content resulting in increased fiber content, but this is often accompanied by lower lignin production that increases fiber digestibility.

Forage quality of normally pollinated corn

Corn has two peaks in forage quality: one at pollination and one at harvest maturity (Figure 1). The early peak in forage quality at pollination is high in quality but too wet for ensiling. The later peak is more familiar, and is the one we typically manage for when producing corn silage.

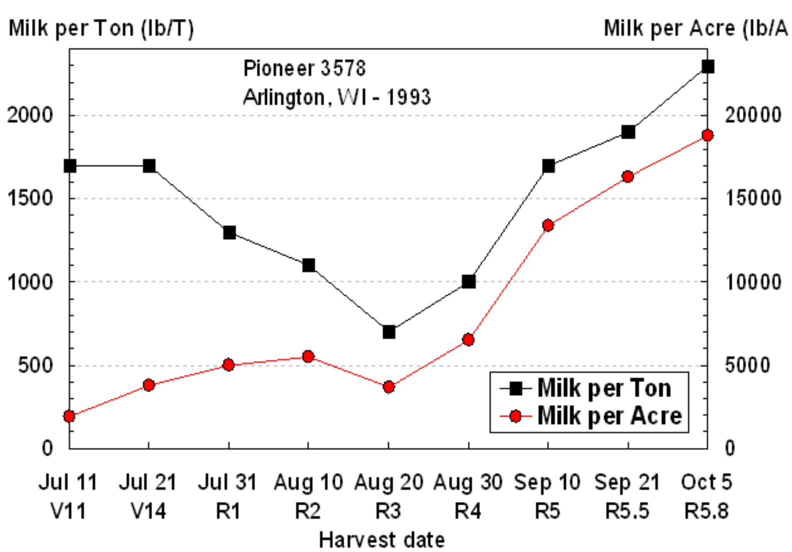

Figure 1. Corn Silage Yield and Quality Changes During Development

Forage quality of poorly pollinated corn

Coors et al. (1997) evaluated the forage quality of corn with 0, 50 and 100% pollination of the kernels on an ear during 1992 and 1993. These years were not considered “drought” stress years, but they can give us an idea as to quality changes occurring due to poor pollination. These plots were harvested in September.

A typical response of corn to stress is to reduce grain yield. Bareness reduced whole-plant yield by 19% (Table 8). Kernels on ears of 50% ear fill treatments were larger and tended to more than make up for reduced numbers (Albrecht, personal communication). With the exception of protein, as ear fill increased, whole-plant forage quality increased.

Table 8. Forage yield and quality of corn with differing amounts of pollination grown at Madison in 1992 and 1993 (n= 24).

Ear fill	Forage yield	Crude protein	NDF	ADF	IVTD	NDFD
%	% of control	%	%	%	%	%
0	81	8.5	57	30	74	52
54	93	8.0	54	28	76	52
100 (control)	100	7.5	49	26	77	54
LSD (0.05)	6	0.3	1	1	1	1

derived from Coors et al., 1997

Forage moisture

If the decision is made to harvest the crop for ensiling, the main consideration will be proper moisture for storage and fermentation. The crop will look drier than it really is, so moisture testing will be critical. Be sure to test whole-plant moisture of chopped corn to assure yourself that acceptable fermentation will occur. Use a forced air dryer (i.e. Koster), oven, microwave, electronic forage tester, NIR, or the rapid "Grab-Test" method for your determination. With the "Grab-Test" method (as described by Hicks, Minnesota), a handful of finely cut plant material is squeezed as tightly as possible for 90 seconds. Release the grip and note the condition of the ball of plant material in the hand.

- If juice runs freely or shows between the fingers, the crop contains 75 to 85% moisture.
- If the ball holds its shape and the hand is moist, the material contains 70 to 75% moisture.
- If the ball expands slowly and no dampness appears on the hand, the material contains 60 to 70% moisture.
- If the ball springs out in the opening hand, the crop contains less than 60% moisture.

The proper harvest moisture content depends upon the storage structure, but is the same for drought stressed and normal corn. Harvesting should be done at the moisture content that ensures good preservation and storage: 65-70% in horizontal silos (trenches, bunkers, bags), 60-65% in upright stave silos, and 55-65% in upright oxygen limiting silos.

Raising the bar

Depending upon farm forage needs, raising the cutter-bar on the silage chopper reduces yield but increases quality. For example, raising cutting height reduced yield by 15%, but improved quality so that Milk per acre of corn silage was only reduced 3-4% (Lauer, Wisconsin). In addition the plant parts with highest nitrate concentrations remain in the field (Table 9).

Nitrate problems

If drought-stressed corn is ensiled at the proper moisture content and other steps are followed to provide good quality silage, nitrate testing should not be necessary. The risk of nitrate poisoning increases as pollination becomes poorer. Nitrate problems are often related to concentration (i.e. the greater the yield the less chance of high nitrate concentration in the forage).

If pollination is poor only about 50 to 75% of the dry matter will be produced compared to normal corn forage.

Table 9. NO_3N of corn plant parts.

Plant part	NO_3N
	ppm
Leaves	64
Ears	17
Upper 1/3 of stalk	153
Middle 1/3 of stalk	803
Lower 1/3 of stalk	5524
Whole plant	978

derived from Hicks, Minnesota

It is prudent to follow precautions regarding dangers of nitrate toxicity to livestock (especially with grazing and green-chopping) and silo-gasses to humans when dealing with drought-stressed corn. Nitrates absorbed from the soil by plant roots are normally incorporated into plant tissue as amino acids, proteins, and other nitrogenous compounds. Thus, the concentration of nitrate in the plant is usually low. The primary site for converting nitrates to these products is in growing green leaves. Under unfavorable growing conditions, especially drought, this conversion process is slowed, causing nitrate to accumulate in the stalks, stems, and other conductive tissue. The highest concentration of nitrates is in the lower part of the stalk or stem. If moisture conditions improve, the conversion process accelerates and within a few days nitrate levels in the plant returns to normal. Nitrate concentration usually decreases during silage fermentation by one-third to one-half, therefore sampling one or two weeks after filling will be more accurate than sampling during filling. If the plants contain nitrates, a brown cloud may develop around your silo. This cloud contains highly toxic gases and people and livestock should stay out of the area. The resulting energy value of drought-stressed corn silage is usually lower than good silage but not as low as it appears based on grain content. The only way to know the actual composition of drought-stressed corn silage is to have it tested by a good analysis lab.

Marshfield Plant and Soil Analysis Laboratory
8396 Yellowstone Dr.
Marshfield, WI 54449-8401
Phone: (715) 387-2523

Estimating Yield

Growers need to carefully monitor, inspect, and dissect plants in their own fields as to plant survival potential, kernel stages, and plant moisture contents in determining when to begin silage harvest. Fields and corn hybrids within fields vary greatly in stress condition and maturity. Often questions arise as to the value of drought-stressed corn. In order to estimate pre-harvest silage yields, the National Corn Handbook publication "Utilizing Drought-Damaged Corn" describes methods based on either corn grain yields or plant height (if little or no grain yield is expected). Below is a summary of this publication.

Grain yield method for estimating silage yield

For moisture-stressed corn, about 1 ton of silage per acre can be obtained for each 5 bushels of grain per acre. For example, if you expect a grain yield of 50 bushels per acre, you will get about 10 tons/acre of 30% dry matter silage (3 tons/acre dry matter yield). For corn yielding more than 100 bushels per acre, about 1 ton of silage per acre can be expected for each 6 to 7 bushels of grain per acre. For example, corn yielding 125 bushels of grain per acre, corn silage yields will be 18 to 20 tons per acre at 30% dry matter (5 to 6 tons per acre dry matter yield). See also Table 2 in A1178 "Corn silage for the dairy ration."

Plant height method for estimating silage yield

If little or no grain is expected, a rough estimate of yield can be made assuming that 1 ton of 30% dry matter silage can be obtained for each foot of plant height (excluding the tassel). For example, corn at 3 to 4 feet will produce about 3 to 4 tons per acre of silage at 30% dry matter (about 1 ton per acre of dry matter).

References and Further Reading

Afuakwa, J. J. and R. K. Crookston. 1984. Using the kernel milk line to visually monitor grain maturity in maize. Crop Sci. 24:687-691.

Carter, P.R. 1991. Corn development and growing degree days. Agronomy Advice Mimeo Series 28.10.

Carter, P. R. and K. D. Hudelson. 1988. Influence of simulated wind lodging on corn growth and grain yield. J. Prod. Agric. 1:295-299.

Coors, J. G., Albrecht, K. A., and Bures, E. J. 1997. Ear-fill effects on yield and quality of silage corn. Crop Science 37:243-247.

Mitchell, V.L., and R.W. Larsen. 1981. Growing degree days for corn in Wisconsin. UWEX. 22 pp.

Rhoads, F. M. and Bennett, J. M. 1990. Corn. *In* Stewart, B. A. and Nielsen, D. R. (editors). Irrigation of agricultural crops. p. 569-596. ASA-CSSA-SSSA, Madison, WI.

Ritchie, S. W., J. J. Hanway, and G. O. Benson. 1993. How a corn plant develops. Iowa State University CES Special Report No. 48. 21 pp.

Shaw, Robert H. 1988. Climate requirement. *In* Sprague, G. F. and Dudley, J. W. (editors). Corn and Corn Improvement. p. 609-638. American Society of Agronomy, Madison, WI.

Vorst, J. V. 1990. Assessing Hail Damage to Corn. National Corn Handbook NCH-1:4 pp.

Growing Season Characteristics and Requirements in the Corn Belt (NCH-40) www.agcom.purdue.edu/AgCom/Pubs/NCH/NCH-40.html

Utilizing Drought-Damaged Corn (NCH-58) www.agcom.purdue.edu/AgCom/Pubs/NCH/NCH-58.html

Weather Stress in the Corn Crop (NCH-18) www.agcom.purdue.edu/AgCom/Pubs/NCH/NCH-18.html

PREDICTING DRY MATTER INTAKE AND MANURE PRODUCTION OF GRAZING DAIRY COWS

Dennis R.Cosgrove and Dennis P. Cooper[1]

Introduction

Rotational grazing has become a well established method for feeding animals on Wisconsin dairy farms. Currently over 20% of Wisconsin dairy farmers use rotational grazing for feeding animals during the growing season. (Ostrom, 2000) Milk production on dairy farms utilizing rotational grazing is typically lower than that from conventional farms. Kriegl has shown 5000 lb/cow less milk from rotationally grazed cows (Kriegl, 2005). This is in part related to less feed intake and also to smaller cow size compared to conventional farms. The same study has shown increased profit per cow and per cwt on grazing farms.

Manure production estimates are an important part of nutrient management planning. Estimates for cows in confinement range from 106 to 148 depending on cow size. Due to smaller size and lower feed intakes these estimates may not be accurate for grazing dairy cows. The current study began in 2003 to determine pasture intakes and manure production from dairy cows on pasture in an effort to develop more accurate nutrient management planning capabilities for these farms.

Materials and Methods

Seven grazing dairy farms throughout Wisconsin were selected to participate in the study. Prior to a grazing event, pasture samples were obtained for quality analysis. Yield estimates were made by clipping the pasture before and after grazing. Supplemental feed levels were documented and feeds sampled. Milk yields during the grazing period were determined from bulk tank measurements. Milk and manure samples were obtained and analyzed.

Intake Estimates

Intakes were estimated by a net energy balance where net energy intake from supplemental feed was known. Total energy excreted in milk was also known. The difference was net energy provided from pasture intake. As net energy concentration of pasture was also known we were able to calculate the amount of pasture intake required to provide the net energy difference between that from concentrate and that excreted in milk.

Manure Production Estimates

Manure production was estimated based on total phosphorus intake and excretion. Phosphorus concentration of all feeds was determined through testing. Total feed consumption was known as described previously. Thus total phosphorus intakes could be determined. Phosphorus excretion would be either through milk or manure. Phosphorus excretion in milk was determined through sampling and bulk tank measurements. Phosphorus excreted in manure would be the difference between P intake and P excretion in milk. Phosphorus concentrations in manure were determined through testing. Thus, we were able to calculate the amount of manure production required to excrete that amount of phosphorus.

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Results and Discussion

The results of the quality sampling are shown in Table 1. The quality was quite consistent from sample date to sample date indicating that variation in pasture quality is low providing the pastures are well managed and grazed at the proper height as these were. The pasture quality was quite high. Crude Protein (CP), Neutral Detergent Fiber (NDF), NDF Digestibility (NDFD), Net Energy (NEl) and Relative Forage Quality all met or exceeded that of bud stage alfalfa. NEl values were similar to corn silage. This indicates that the decreased milk production experienced by many grazing farms relative to confinement dairies is not related to low forage quality.

Table 1. Quality of pastures forage samples

Year	CP	NDF	NDFD	NEl	RFQ
	----------------------%---------------------			Mcal/lb	
2003	19.8	44.6	63.3	0.74	187
2004	21.0	43.3	61.1	0.75	208
2005	22.9	40.7	69.7	0.75	209

Intake data are presented in Table 2. Pasture intake was again consistent form year to year at approximately 20 lb/cow/day. Supplemental feeds consisted mainly of corn grain and occasionally dry hay or haylage. Total intake averaged 36 lb/cow/day. This intake level is sufficient to support the 51 lb/cow/day milk production which was observed on these farms. In order to produce more milk, even with the high forage quality, these cows would need to eat significantly more feed. This relatively low intake is likely the caused of decreased milk production on grazing farms.

Table 2. Pasture, supplement and total intake and milk production of 7 grazing herds.

	Intake			Milk
Year	Pasture	Supplement	Total	production
	----------------------------lb/day----------------------------------			
2003	20.8 ± 3.1	15.5	36.3	48.8
2004	20.5 ± 2.3	14.9	35.7	52.7
2005	20.0 ± 2.7	16.4	36.4	52.4
AVE	20.3 ± 1.9	15.6	36.1	51.3 .

Manure production by cows in these herds averaged 85.5 lb/cow/day (Table 3). This is significantly less than the current values used for nutrient management planning. Those standards call for a 1000 lb and 1400 lb lactating cow to produce 106 lb and 148 lb of manure/day respectively. (ASAE, 1993) The cows in this study weighed 1200 lb on average.

Table 3. Phosphorus content and total manure production by grazing dairy cows

Year	P2O5	Manure .
	lb/ton	lb/cow/d
2003	6.0 ± 0.8	77.5 ± 13.3
2004	7.1 ± 0.9	88. 7± 20.8
2005	5.6 ± 0.6	90.3 ± 8.8.
Ave	6.4 ± 0.5	86.4 ± 10.4.

Conclusion

Nutrient management planning for grazing dairy farms needs a different approach than that for confinement dairies. Manure deposition by cows on pasture needs to be considered when calculating the total nutrient load. This is done by determining how many cows were on a given paddock and for how long. Manure deposition may then be determined by multiplying these values by the pounds of manure produced per cow per day. The results of this study suggest that the current manure production values are too high for a typical grazing cow and that a value of 85 lb/cow/day is more appropriate.

References

American Society of Agricultural Enngineers (ASAE). 1993. Manure production and characteristics. ASAE Standards D384.1. Agric. Engr. Yearbook. ASAE, St. Joseph, MI

Kriegl, T. 2005. Dairy grazing farms financial summary: Regional/multi-state interpretation of small farm data. Fifth Year Report. UW Center for Dairy Profitability, Madison, WI.

Ostrom, M.R., and D.B. Jackson-Smith. 2000. The use and performance of management intensive rotational grazing among Wisconsin dairy farms in the 1990s. Research Report 8. Program on Agric. Technol. Studies. Univ. of Wisconsin-Madison, Madison, WI.

RECLASSIFICATION OF WISCONSIN SOILS

Don Fehrenbacher [1/]

{This page provided for note taking}

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DEMONSTRATION OF NEW WEB SOIL SURVEY TOOL

Ken Pena [1/]

{This page provided for note taking}

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INVASIVE INSECTS CREATE OPPORTUNITIES

R. Chris Williamson [1/]

Less than 1% of all insect species are considered "pests"! Of these, approximately 40% are exotic or invasive species in the United States. Each year millions of dollars are spent to control insects. Gypsy moth, Japanese beetle, and emerald ash borer are invasive insect species that are problematic in the United States.

Gypsy moth presents as challenge in that it is not only a pest in the urban landscape, but it too causes damage in forest ecosystem as well. Gypsy moth is know to feed on over 300 plant species, however oak (*Quercus* spp.) are especially preferred. The caterpillar stage is the primarily the destructive life stage, however the egg masses, pupal cases (cocoons), and adults are often considered a nuisance. Gypsy moth caterpillars are fairly easy to control. Most contact insecticides provide excellent control, however, the difficulty is the placement or application of the control agent. During their first few caterpillar stages, gypsy moth spends the majority (day and night) of its time in the canopy of the trees. Thus, depending on the tree height, application may be difficult. Once the gypsy moth caterpillars begin to develop and mature, they take-on a different behavior whereby they are only active at night. Smaller, younger caterpillars are typically easier to control, this is especially true for biologically based insecticides such as *Bacillus thuringiensis kurstaki* also know as Btk. Another, alternative control strategy is destroying gypsy moth egg masses. Egg masses can be destroyed using Golden Pest Spray Oil (GPSO), GPSO is directly applied to the egg masses, a procedure called "oiling." GPSO acts as a suffocant, not allowing the egg to hatch.

Japanese beetle is also a troublesome invasive insect species. This pest presents a problem from two perspectives: (1) the adults cause feeding damage to the foliage of woody ornamental plant material and (2) the larvae (grubs) cause damage to the roots of turfgrass as well as ornamental plant material. The control strategies for adults and grubs are quite different. Adult control strategies rely primarily on curative (corrective) insecticide treatment applications, whereby grub control strategies are often reliant on preventative insecticides, especially where a history of grub damage has occurred. Most contact insecticides are effective against Japanese beetle adults; however, the best time to apply the control agents is when the beetles are most active. Japanese beetle adults are sun-loving animals, thus they are most active on sunny day, especially in the upper canopy of the tree typically on the Southern and Western exposure. As for the grubs, they can be difficult to control, especially as they develop and mature, larger grubs the most difficult to control. For this reason, timing of treatment applications is crucial! Moreover, preventative insecticide treatments are often more effective since they are targeted at measurably smaller, newly hatched grubs. Regardless of the management strategy, ALL insecticide treatments for control of white grubs MUST be watered or irrigated with at least 0.25 inch of water to aid movement of the product to the grub located in the soil beneath the turf.

The emerald ash borer (EAB) was first discovered in June 2002 in the Detroit, Michigan metropolitan area. Since then, EAB has been found in Ohio, Indiana, Maryland, Illinois, and Ontario, Canada. EAB is an invasive insect that is native to Asia. EAB is a wood boring insect that is only known to attack ash trees (i.e., *Fraxinus spp.*). The larvae (immature life stage) cause

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damage to ash trees by destroying conductive tissues responsible for the transportation of nutrients and water. It has been estimated that >20 million ash trees are either dead or dying as a result of this insect pest. EAB was discovered <40 miles from the southern Wisconsin border in nearby northern Illinois. It is theorized that the most likely means by which EAB spreads is through the movement of ash products including firewood, nursery stock and wood products such as pallets and logs. To date, EAB has not been discovered in Wisconsin, thus no insecticide manage-ment treatment are recommended. Once EAB is discovered in Wisconsin, the Wisconsin Department of Agriculture, Trade and Consumer Protection plans to initiate an eradication process whereby all ash trees within a half-mile radius of an EAB find will be felled (removed) and destroyed. For additional information, including management, regarding EAB, visit our EAB website at **www.entomology.wisc.edu/emeraldashborer**.

SOYBEAN APHID IPM – AN OVERVIEW FOR 2007

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RISK OF SUDDEN DEATH SYNDROME IN WISCONSIN

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Introduction

Sudden death syndrome (SDS) of soybeans, causal agent *Fusarium solani* f. sp. *glycines*, has been observed frequently in soybean fields in the North central states since the early 1990s. Symptoms of SDS had been observed in Wisconsin previously, and the causal agent was confirmed by laboratory analysis in 2006. Nine counties are now confirmed to have positive SDS reports (Figure 1).

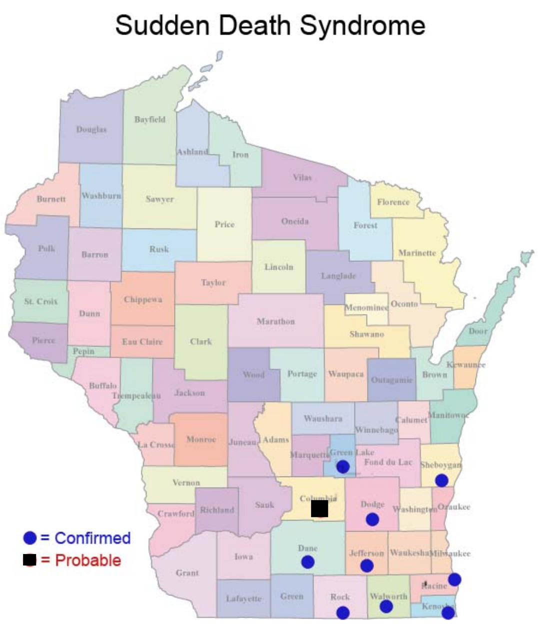

Figure 1. SDS has been confirmed in nine counties in Wisconsin, and likely to be found in at least one more.

Symptoms

The first symptoms of SDS are usually observed on the foliage (Figure 2). Leaves are characterized by interveinal necrosis and chlorosis, indistinguishable from the symptoms of brown stem rot. Despite the similarity of foliar symptoms, SDS symptoms can be separated from those of BSR by observing the timing of symptoms, absence of internal stem discoloration, and degree of root rot. Symptoms of SDS become apparent earlier in the reproductive phase, usually

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R3 or R4, in comparison to R5 or R6 for BSR symptoms. Often, as leaves drop, petioles will remain attached to the stem in soybeans infected by the SDS pathogen. Internal discoloration in the stem is not observed beyond lower nodes with SDS symptoms. Roots may be brown and stunted due to root rot caused by the SDS pathogen and not so for BSR. Often, the location of infected plants may be limited to an area where water had been sitting for sometime, or along a wet portion of the field.

Figure 2. Interveinal necrosis and chlorosis foliar symptoms typical of Sudden death syndrome.

Epidemiology

SDS severity varies from year to year because of the influence of environment, especially soil moisture and temperature. High soil moisture, especially in the early months of growth, increases severity of foliar symptoms (Roy et al., 1989; Rupe et al., 1993; Vick et al., 2001). Studies in controlled temperature facilities showed that disease was more severe at cooler soil temperatures and higher soil moistures, and that each factor affected disease development independent of the other (Vest et al., 2001). Additionally, cooler temperatures during the early reproductive stages are reported to increase disease severity (Roy et al., 1997).

Yield loss due to SDS can be significant, even in the absence of foliar symptoms (Njiti, et al. 1998; Luo, et al. 2000). Yield loss factors include lower seed weight and quantity, especially when symptoms appear before growth stage R5.5. While yield losses may be near 100% in some areas in years of high disease pressure, year to year environmental variability, coupled with field variability may result in sporadic yield loss in a given area (Hartman, 1995). Yield loss caused by SDS in Wisconsin is not known.

Often, symptoms of SDS can serve as an indicator for presence of soybean cyst nematode (SCN). Typically a problem of high yield soybeans, presence of SDS may also indicate presence of soybean cyst nematode (SCN), a serious pest of soybean. Field and greenhouse studies have shown SDS foliar severity is greater in when SCN is present (Xing and Westphal, 2006; Gao et al., 2006). The SDS pathogen has been found to colonize cysts of SCN, which may accounts for common simultaneous occurrences of both pathogens (Roy, et al. 2000).

Management Strategies for SDS

Management of SDS can be achieved by use of resistant or moderately resistant cultivars. SDS resistance varies widely by soybean variety (Figure 3). As prevalence of SDS has increased, companies are including SDS ratings for their product lines. An informal survey of seed company soybean product lines indicated 57% of the listed varieties were characterized for SDS resistance. Individual seed companies reported an SDS rating for 37 to 62% of their product line adapted to Wisconsin. Most of the varieties were given a rating of moderate resistance rather than resistant. It is notable however, that not all seed companies screen for SDS, so it is important for growers and consultants to be aware of the potential risks. Because presence of SCN can alter a cultivar's reaction to the SDS pathogen, it is desirable to utilize a cultivar with SCN resistance to limit yield loss. The majority of the seed companies have data on SCN resistance for their varieties so an effective management strategy may be implemented around variety selection.

Figure 3. SDS susceptible soybean variety surrounded by a variety with resistance. Note the susceptible variety is very chlorotic, shorter and does not have canopy closure.

Cultural practices can be part of an SDS management strategy. Correcting or limiting soil compaction may reduce amount of SDS development. In areas where compaction is problematic, subsoiling can increase porosity, decrease water-holding capacity, and reduce disease severity substantially (Vick et al., 2001). Severity of SDS is reported to increase as sand content in soil increases, but decreased as soil pH was lowered from 7.7 to 5.5 (Sanogo and Yang, 2001). Delayed planting may have some effect on limiting losses due to SDS (Rupe and Gbur, 1995). The effect of planting date may be related to soil temperature. Cooler soil temperatures have been shown to increase severity of SDS. Late planting must be balanced with other potential disease risks, however. Increased soybean aphid pressure and virus incidence are associated with later plantings. Severity of SDS has been found to be greater in no till systems, presumably because of cooler soil temperatures, increased moisture and greater residue reserves that harbor pathogen inoculum. (Von Qualen et al., 1989; Wrather et al., 1990). Crop rotation and crop sequence does not influence SDS severity. (Rupe and Hartman, 1999).

The increased presence of SDS in Wisconsin fields will mandate careful scouting practices. Because there is not one management option that will prevent yield losses, a multi-faceted approach will need to be taken. By careful scouting for SDS and SCN, choice of a resistant soybean variety and utilizing cultural practices that do not favor disease development, growers will be able to effectively manage this new threat.

References

Boerma, H.R., and J.E. Specht (ed.). 2004. Soybeans: Improvement, production and uses. 3rd ed. ASA Press, 2004.

Gao, X., T.A. Jackson, G.L. Hartman, and T.L. Niblack. 2006. Interactions between the soybean cyst nematode and Fusarium solani f.sp. glycines based on greenhouse factorial experiments. Phytopathology 96(12):1409-1415.

Hartman, G.L., G.R. Noel, and L.E. Gray. 1995. Occurrence of soybean sudden death syndrome in east-central Illinois and associated yield losses. Plant Dis. 79:314-318.

Luo, Y., K. Hildebrand, S.K. Chong, O. Myers, and J.S. Russin. 2000. Soybean yield loss to sudden death syndrome in relation to symptom expression and root colonization by Fusarium solani f. sp. glycines. Plant Dis. 84:914-920.

Njiti, V.N., M.A. Shenaut, R.J. Suttner, M.E. Schmidt, and P.T. Gibson. 1998. Relationship between sudden death syndrome disease measures and yield components in F6-derived lines. Crop Sci. 38:673-678.

Roy, K.W., M.V. Patel, and R.E. Baird. 2000. Colonization of Heterodera glycines cysts by *Fusarium solani* form A, the cause of sudden death syndrome, and other Fusaria in soybean fields in the midwestern and southern United States. Phytoprotection 81:57-67.

Rupe, J.C., and G.L. Hartman. 1999. Sudden death syndrome. p. 37-39 *In* G.L. Hartman, J.B. Sinclair, and J.C. Rupe (ed), Compendium of soybean diseases. 4th ed. APS Press. St. Paul, MN.

Rupe, J.C., R.T. Robbins, C.M. Becton, W.A. Sabbe, and E.E. Gbur, Jr. 1999. Vertical and temporal distribution of Fusarium solani and Heterodera glycines in fields with sudden death syndrome of soybean. Soil Biol. Biochem. 31:245-251.

Rupe, J.C., W.E. Sabbe, R.T. Robbins, and E.E. Gbur, Jr. 1993. Soil and plant factors associated with sudden death syndrome of soybean. J. Prod. Agric. 6:218-221.

Vest, J.D. and J.S. Russin. 2001. Effects of soil temperature, moisture, and planting date on soybean sudden death syndrome root and foliar disease. Phytopathology 91:S91-92.

Vick, C.M, S.K. Chong, J.P Bond, and J.S. Russin. 2001. Sudden death syndrome and the soil physical environment: a two-year study. Phytopathology 91:S92.

Von Qualen, R.H., T.S. Abney, D.M. Huber, and M.M. Schreiber. 1989. Effects of rotation, tillage, and fumigation on premature dying of soybeans. Plant Dis. 73:740-744.

Xing. L.J. and A. Westphal. 2006. Interactions of Fusarium solani f. sp. glycines and Heterodera glycines in Sudden Death Syndrome of Soybean. Phytopathology 96(7):763-770.

NEW SOIL PATHOGEN TESTS FROM THE UW

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EXOTIC THREATS 101

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Increased world trade has made the movement of goods and people easier and more common; with that increased movement, has come increased potential for the movement of pests. Two current exotic threats to Wisconsin (emerald ash borer, an insect pest of ash trees, and potato cyst nematode, an agricultural threat) will be examined to outline the ways in which pests may be transported to new regions, the systems in place for prevention and early detection, and the role of various players—particularly growers and crop consultants—in safeguarding Wisconsin's agriculture and environment.

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